SCIENCE INFORMATION NOTES

A collection of articles on scientific and technological topics, research policies, science and society, higher learning, etc.

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I N D I A N N A T I O N A L S C I E N C E A C A D E M Y

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A Strategy for Economic Growth of the LDC's Through the Application of Science and Technology

by H. Harry Szmant*

For about three decades the world has witnessed numerous national, regional and international conferences, workshops and symposia designed to bring science and technology to bear on narrowing the gap that exists between the "haves and the have nots", the rich and the poor, or the industrially developed and underdeveloped countries. Eventually, the spirit of these discussions became translated into foreign aid programs focused on improving the scientific level of the less developed countries (LDCs). Some programs concentrated on improving the general scientific education of the young by developing new instructional materials and techniques, and by the modernization of laboratory facilities. Other programs concentrated on strengthening the teaching and research potential at the university level by promoting exchanges of faculty and cooperative research. As we all know, countless scholarships have been awarded to individuals from LDCs to study and/or to do research to the prestigious academic institutions of the industrially developed world. However, the result of these conferences and foreign aid programs has been negligible because the above mentioned gap has not been reduced significantly, certainly not at a pace that matches the rising demographic pressures and economic aspirations of most LDCs. A possible exception to this conclusion are the oil-rich countries, but even some of these nouveau riche members of the community of nations have basically remained underdeveloped while accumulating gigantic debts because of frivolous and nonproductive spending sprees. On the other hand, the efforts to bring science and technology into the developmental equation has created in many LDCs a scientific infrastructure of highly educated scientists and well-equipped laboratories and libraries. In some of the laboratories there is ongoing scientific research that is, most often, an extension of the experiences acquired abroad. However, many of such scientists who work in the LDCs become, sooner or later, disenchanted and frustrated because the environment in which they function is very different from what they experienced during their foreign educational/research visits. It is not necessary to spell out here the nature of these environmental differences. Perhaps an important contribution to disenchantment and frustration that prevail among many scientists of the LDCs is the realization that the problems of underdevelopment, namely unemployment, underemployment, poverty, hunger and all the consequences of the above, do not seem to be ameliorated by their scientific work. It is easy to understand how such feelings of impotence

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can lead to frustration and emigration, and the "brain drain" empoverishes the LDCs in the technically specialized human resources that are scarce to start with.

An objective evaluation of the socio-economic changes that have transpired during the last quarter of the century suggest that neither an improvement of science teaching at the elementary level, nor the creation of cadres of highly educated scientists, have interrupted the "self-perpetuating cycle of underdevelopment" or contributed significantly to the economic progress of the LDCs even under conditions of political tranquility. In the absence of tranquility, it is difficult to expect much economic growth except by way of an influx of foreign investment capital, but the latter shies away from turmoil and thus cannot contribute to a desired self-perpetuating economic growth process.

Now, let us consider briefly how our chemical discipline has fared, relative to the other scientific areas, during the decades of foreign aid programs.

In the first place, chemistry has not received the share of attention from the planers and sponsors of foreign aid programs that is proportional to its contribution to the GNP of an industrially developed country. For example if we consider the fact that the value of recorded shipments of chemicals and products of industries that are heavily dependent on chemical processes (pulp and paper, petroleum, rubber, stone, clay and glass, and so on) contributed in 1982 over 20% of the GNP of the U.S.A. then it follows that about 20% of all foreign aid designed to increase the economic welfare of the LDC should have been concentrated on the build-up of human resources with a specialization in chemistry. Obviously, this is not the history of foreign aid and internal development programs, and chemistry competes not too favorable with other disciplines that have less direct impacts on the economy. Often, the disciplines that are promoted are chosen on the basis of local, accidental and personal preferences or are a reflection of fashionable trends that arise in the industrially developed countries. Naturally, such policies can be justified by invoking the truisms that, eventually, all the progress in all of the sciences benefits humanity, that the world needs inter-and multi-disciplinary approaches to the solution of its problems, or that one must start with the most basic among the different disciplines.

In the second place, much of the chemistry-based efforts and activities in the LDCs deal with the acquisition of knowledge and experience that has little to do with the satisfaction of the pressing needs of the LDCs. Again, one can justify this situation by means of the truisms that any kind of high-level, professional experience prepares one

(and his students) for future work on the problems of one's country because scientific methodology and techniques are universal.

We concluded above that the last quarter of a century brought little inprovement in the socio-economic situation of the LDCs through contributions of either general or chemical science and technology. Can we afford to wait another quarter of a century for the fruition of socio-economic progress, or should we reexamine the past and on-going efforts in order that they may become more effective?

Personally, I do not believe that we can afford to procrastinate in the search of remedial actions unless we are prepared to accept bloodshed and other forms of human suffering as the price of changes born out of despair and violence of hopeless people, changes that, in the long run, still do not improve the general well being of the LDC.

This rather lengthy intraduction is intended to present a historical perspective and a rationale for a proposed strategy to remedy the economic stagnation of the LDCs. We shall concentrate here on the mobilization of the human resources in the area of chemistry not only because this is the professional area of the undersigned, but also because it is chemistry that serves to transform all sorts of material resources for the economic benefit of humanity.

THE STRATEGIC PLAN

Other than societal tranquility, there are two important conditions that must be fulfilled in order that chemical science and technology may be harnessed to propel a healthy process of economic growth. They are, first, a condition of understanding, respect and cooperation between the technical personnel and the government as well as the financial, educational, informational and productive (i.e. agriculture, forestry, manufacturing, mining, construction, etc.) sectors of the economy of a given LDC. Secondly, the intellectual orientation of a significant fraction of the chemists and chemical engineers of the LDC must be oriented towards the development of viable, local technologies that create new wealth from whatever resources are found in the given country. The task of propelling an economic growth process requires that both conditions are fulfilled at the same time. We shall now address the realization of these conditions.

One can visualize the process of economic development through the application of chemistry to consist of three phases: induction, preparation and production.

The first phase of the process, referred to here as INDUCTION, is meant to create a general understanding among

the chemists and non-chemists of the given society of the task that needs to be accomplished. It is meant to avoid halfhearted and isolated efforts of the past that produced discouragement and frustrations. It requires that the leaders of the given society, their delegates in the government, and representatives of the banking institutions and of the different sectors of the existing economy become aware of the opportunities for economic growth, sympathize with these efforts and cooperate through moral and practical support of the technical personnel involved in this task.

In order to achieve this ambience of understanding and collaboration, the induction phase can begin with the organization of meetings of both technical and non-technical components of society for the purpose of the following discussions.

1. Analysis of the national economy from a chemical viewpoint:

   a) Production and consumption of raw materials, intermediates and finished products used in agriculture, mining, the construction industry, manufacturing, transportation, and other sectors of the economy;

   b) The utilization, generation, conservation, and potential production of energy.

2. General analysis of renewable resources and their potential utilization in the economy through value-added transformations. Traditional as well as new sources of renewable resources (biomass) should be considered in view of their impact on agriculture, fishing and forestry.

3. An analysis of commerce from a chemical viewpoint:

   a) Potential import substitution by materials that are either identical to those currently imported or by other materials that perform similar functions;

   b) Potential increases in exports by value-added transformations of traditional export materials or by the creation of new, non-traditional export products.

It is noteworthy that the three above mentioned topics deal with the improvement of the economic situation of the population that labors in the most basic of all economic sectors: agriculture, fishing, forestry, and mining, Thus any progress that can be achieved through an input of chemical science and technology at this level promises to

have profound positive socio-economic effects. Against the background of the current and potential economic picture of the given LDC one can now turn to the next topic:

4. Possible strategies for the mobilization of human, economic and regulatory resources through

   a) individual and cooperative initiatives of private industrial and commercial entities;

   b) public initiatives sponsored by government in the forms of

      (1) coordination of the total effort;
      (2) long-range investments of national financial resources, or loans negotiated by government with international funding agencies;
      (3) regulation of commercial, agricultural and other basic economic activities designed to promote and protect local initiatives;

   c) development of additional human resources required for a successful process of economic growth through an intensive input of chemical science and technology.

A successful INDUCTION phase should achieve a broad concensus concerning the economic growth objectives, identify and prioritize specific areas of action, identify individuals and teams of people dedicated to the pursuit of specific objectives, and, hopefully, create an ambience of enthusiasm and cooperation among the different sectors of society for efforts to be undertaken for the sake of the general good. It is obvious that the contents and results of the INDUCTION period will vary from one country to another and that they will depend on economic, cultural and political circumstances and traditions. However, the efforts to be undertaken should be apolitical as much as it is humanly possible to be free of politics, and an attempt should be made to free whatever agreed upon initiatives from political changes in order to assure continuity of the developmental process.

The induction phase is followed by, what we may call, the Preparation phase, during which individuals and teams of people working in private and/or public, academic and/or industrial facilities demonstrate local know-how of specific technologies. The emphasis here is on local know-how rather than on the installation of imported turn-key production facilities.

These achievements must withstand objective scrutiny and evaluation for quality and economic feasibility. Such

evaluation can, most likely, be carried out by boards composed of individuals who represent the sector or sectors that sponsor the efforts and that are likely to finance the scale-up of the technology towards actual production. The length of the Preparation phase will vary from one project to another and will depend on the complexity of the undertaking. During this phase of the developmental process, the work will require the utilization of whatever scientific and technological infrastructure that was inherited from the past, and it will demand from the participants an exploration of professional facets that were overlooked or ignored in the past. An enthusiastic collaborative effort will be conductive to bringing together different technical disciplines that are often competitive and even antagonistic because of traditional scarcity of professional opportunities in an industrially underdeveloped country.

A successful preparation phase is expected to sort out those projects that are ready for scale-up and entry into the production phase. The promotion of the projects for large-scale implementation must be based on careful evaluation of the internal and external markets and of the competitive situation of the product(s) in the international market place. When applicable, the regulations to provide a limited degree of protection against unscrupulous dumping of identical or similar products must be in place to insure the survival of the fledgling industries without, however, allowing them to remain indefinitely inefficient and non-competitive. Thus, a common sense balance must be struck between the practice of either extreme free market or controlled market philosophies.

As different technological projects enter the production phase, it will become obvious what new technological initiatives are called for in order to achieve both a backward and forward integration of the economy. If necessary the additional technological initiatives may be stimulated by some national committee for the promotion of economic development, but hopefully the entrepreneurial spirit will have become awakened to the point where such public stimuli are not needed.

The economic development program presented above involves serious and persistent work on the part of the technical and non-technical sectors of society. It is not a recipe for a magic, instant transformation of an underdeveloped country, but, on the other hand, it is designed to create a self-sustaining process of economic growth based on grass-root participation of all human resources that are able and needed to contribute to its success.

No doubt, in the context of the above mentioned proposal the question arises of t'e role of foreign uni-and multinational enterprises in the developmental process of the LDCs. My personal belief is that foreign uni-and multinational economic initiatives should be welcomed as long as they are limited by mutual agreement to provide financial and technological resources for extremely large-scale projects. Usually, these involve the production of commodities (petroleum products, steel, minerals, etc.) that require very large capital investments and wide-spread marketing of relatively cheap products at small and highly competitive profit margins. These enterprises represent oases in an otherwise desolate economic landscape and seldom lead to a long-range and broadly expanding industrialization process in a LDC. However, while foreign uni- and multinational industrial enterprises fulfill a certain need in the total economy of the LDC, they cannot be depended upon to create a self-perpetuating process of economic growth. The wisest policy for the LDC to follow is to utilize the economic benefits from foreign uni-or multinational enterprises to underwrite the costs of the economic development program described above rather than distribute these economic benefits for immediate gratification of desirable, but unproductive, expenditures. Here, precisely, resides the wisdom and the good intentions of those who govern a given LDC and who, after all, should be held responsible for its future. The proposed interaction between the technical and official segments of society should deepen the wisdom and improve the intentions of the latter.

We shall now turn to the second condition required for a successful pursuit of the proposed strategy of economic growth through chemistry, namely the build-up of a sufficient number of chemical professionals who are adequately prepared for the initiation and execution of the technical initiatives that constitute the framework of economic development. The chemical professionals in question belong to the often non-communicating, and even hostile, groups of chemists and chemical engineers.

The traditional education of chemists usually lacks the detailed understanding of the involvement of chemistry in the economy of a modern society and the traditional education of chemical engineers usually lacks a detailed understanding of the chemical nature and economic potential of chemical transformations. The deficiencies of both groups of chemical professionals can be remedied, and a bridge between these two groups can be built, by a fully structured educational experience that, for the lack of a better term, we may call industrial chemistry. A fully structured course by that name should consist of components that can be calassified into two categories of learning experiences

A. Modus operandi of industrial chemistry

1. Chemistry of industrial processes, i.e. the sources and transformations of materials.

2. Economic considerations in the choice of different industrial processes, i.e. inter-process competition based on differences in the costs of materials, equipment and energy, selectivity, environmental considerations, etc., and the problems of scale-up from laboratory through pilot plant to production facility.

3. Marketing, sales and distribution of the products and business strategies of the chemical and allied industries. Differences in the production of commodity, intermediate and specialty materials. The organization of chemical enterprises.

B. Modus cogitandi of industrial chemistry.

1. The utilization of chemicals in the market place, i.e. the relationship between chemical structure and/or composition of materials, the resulting properties and consequent applications, and the compromise between performance and cost.

2. The development of a product in a competitive world, i.e. interproduct competition.

3. The cultivation of the enterpreneurial spirit, i.e. the recognition of new economic opportunities for the production of marketable chemicals.

An inspection of the above mentioned components of a fully structured learning experience referred to here as Industrial Chemistry, suggests that component A-1 is accessible by means of several texts and monographs, journals and, above all, through works like the Kirk-Othmer "Encyclopedia of Chemical Technology". However, relatively little is available on the subject of the industrial potential of renewable resources, a subject of great importance to LDCs that must structure their economic growth on abundant biomass. The topics of component A-1 are seldom taught in current academic programs of either chemists or chemical engineers. It is my personal conviction that teaching this subject matter requires a full-time commitment on the part of the teacher because of the constant changes that occur in the real world of the chemical and allied industries.

Component A-2 is a usual portion of the chemical engineering curriculum, but in the absence of sufficient chemical depth, the learning experience is rather abstract

and the difference between a model situation and the real world behavior of chemicals may cause difficulties in daily operations.

Component A-3 is a normal portion of the programs of Colleges of Business and Administration, but the non-chemical teachers of these specific subjects cannot infuse the chemical reality into their generalized presentations.

Components B of the fully structured Industrial Chemistry learning experience are very elusive and, to the best of my knowledge, are not readily accessible by way of textbooks or monographs. Hence, again, it is a subject matter that must be assembled by the efforts of full-time, dedicated teachers. Unfortunately time and circumstances do not permit here to elaborate on some of the educational components suggested above by means of examples that have been evolved over the past dozen years of teaching by the undersigned. However, the importance of Industrial Chemistry to the future of the LDCs seems obvious. It is logical that the effort to assemble and divulge the above mentioned, and perhaps additional, educational components of Industrial Chemistry, should become a fruitful objective of organism occupied with the promotion of the well being of the LDCs and with the solution of their socio-economic problems.

Conclusion

The experience of the last three decades of efforts to improve the status of the LDCs teaches us that it is useless for scientists, in general, or chemical professionals, in particular, to proclaim to each other the importance of their disciplines. After the echo of the last speech fades away, and after all proclamations and resolutions are immortalized in impressive but soon to be forgotten documents, life tends to return to the old pattern and unemployment, poverty and hunger continue. By the same token, it is useless for political figures of the world to proclaim the virtues of Science/Technology in Development of the LDCs unless and until the priorities are well thought out in terms of the rate-determining, appropriately oriented human resources. We cannot count on all of the solutions of the socio-economic problems to descend from the seat of government nor can we expect much progress through unilateral efforts of scientista and engineers. The collaboration of both the technical and non-technical circles is required, and the common goal can then be promoted by carefully prioritized foreign aid programs that respond to wise and realistic, locally formulated objectives.

World Status Report on Hydroelectric Energy

by Asit K. Biswas

The use of falling water as a source of energy is not new: it has been harnessed in different parts of the world for at least two thousand years. Over the past decades, the use of hydroelectric energy for various purposes has increased steadily and is likely to continue to do so in the foreseeable future.

Hydroelectric energy generating systems are different from other systems of large-scale energy generation since generating power is not their only purpose. Hydroelectric power is only one purpose, albeit an important one, of river basin development, which includes inter alia, irrigation navigation, flood control, recreation, wildlife enhancement and provision of water for domestic and industrial purposes. The present philosophy is to develop a plan for optimal use of water resources of a river basin, which generally would include hydroelectric generation. Large-scale water resources development projects are no longer considered to be isolated projects, but rather an integral part of a regional, national or even international (when a river passes through two or more countries) development plan.

Development in the Seventies

An objective review of global developments in hydroelectric energy during the past century will indicate that the situation drastically changed in its favour since the oil price increase and boycott of October 1983. In sharp contrast to nuclear power, which has experienced diminishing expectations during the past decade, interest in hydropower development on a global basis has never been higher.

The interest in hydroelectric development has increased significantly in the 1970s due to five important causes. First, increasing fossil fuel prices have made many hydroelectric projects economically viable and attractive. Second, since water is a national resource, hydroelectric development assures a country a reliable source of indigenously produced energy. Third, many countries, faced with serious balance-of-payment deficits, due to the import of fossil fuels, have opted for hydroelectric generation. Fourth, many countries faced severe food crises in the 1970s: in order to increase food production, it is essential to provide irrigation; since dams built for irrigation projects can also generate hydroelectric power, and irrigation is a consumptive use of water but hydropower generation is not, it means that the same water can be effectively used for both electricity generation and irrigation. In other

words, properly planned water development projects can successfully contribute to the resolution of both food and energy crises. Fifth, the technology necessary for hydropower development is well-established and well-known. It does not require as complex a technology as is necessary for nuclear power, and many developing countries now have the required technical expertise to construct dams and hydroelectric power stations, and manage them thereafter. Because of these major reasons, countries that have suitable unexploited dam sites are now planning to develop them.

Global Potential

A detailed and precise inventory of the global hydroelectric potential is still not available, but according to the Survey of Energy Resources, prepared for the Eleventh World Energy Conference, held at Munich in September 1980, hydroelectric energy accounts for nearly 23 per cent of the global electricity supply. It was further estimated that by the year 2020, annual energy from installed hydroelectric facilities in the world will be approximately four times the present capacity.

According to an estimate made by the World Bank in August 1980, roughly half of the world's hydroelectric potential exists in developing countries, totalling nearly 1,200 gW. Approximately 10 per cent of this potential has been developed so far.

Economics of Hydroelectric Development

Two opposing forces have had an impact on the cost of hydropower construction during the past two decades. Advances in planning, design and construction techniques and and power station equipment have reduced costs, but these have been more than compensated by rising costs of land, construction materials and labour. Even though the cost of hydropower development has steadily increased in recent years, in general its cost-escalation index has been lower than thermal and nuclear power stations. This is primarily due to the fact that adverse environmental effects of hydropower projects like compensation for flooded land, rehabilitation of people, restoration of fisheries, etc., have normally been included in construction costs. In contrast, increasing stringency of environmental regulations to control water, air and land pollution and radiation protection has necessitated increased costs for thermal and nuclear power stations.

According to estimates provided by the United Nations Economic Commission for Europe (ECE) in 1981, hydropower plants can be considered viable at costs between US $ 800 and 1,500 per kW. These costs compare favourably with nuclear plants, another capital intensive source of energy.

whose cost per kW ranges between $ 3,000 and $ 5,000 (1976 dollar values). Unlike thermal and nuclear plants, the fuel costs of hydropower plants are negligible.

Recently, the World Bank has provided comparative costs of power generation for oil importing developing countries, derived from typical World Bank projects.

Small-scale Hydro

Current estimates indicate that small-scale hydro projects (under one mW) may account for 5-10 per cent of the world's total hydro potential. It is gaining increasingly wider acceptance in different parts of the world, especially for those remote locations that are not serviced by transmission lines. The World Bank estimates that the economic limit for small-scale hydro projects is in the $2,000-$3,500 per kW range. Since the investment costs are high, they are not usually preferred for use in village systems with low load factors.

Small-scale hydro has been most used in China, where, during the past two decades, some 90,000 such plants have been constructed. The average capacity of these plants is around 70 kW, but the capacity has been steadily increasing over the years. For example, in 1970, the average capacity of plant constructed was 32 kW: by 1980, it had increased to 300 kW. The selling price of electricity from a small-scale hydro plant is about half of that from a small-scale steam plant. While small-scale hydro projects are unlikely to have a significant effect at the national level, their impact at the village level is noteworthy.

Many developing countries like India or Egypt have started to look seriously at small-scale hydro projects. However, their very decentralized nature can make their management and operation a difficult process. Extensive development of small-scale hydro projects in most developing countries is likely to be held back during this decade due to the scarcity of managerial and engineering talents.

Small-scale hydro projects, if properly planned, can be especially effective as an economic and social catalyst for extensive rural development in remote areas.

Environmental Concerns

Like nuclear and thermal power plants, hydroelectric projects have also generated environmental concerns. In general, however, such concerns for hydro projects have not been as intense as with nuclear power plants. During the past 2-3 years, environmental concerns associated with coal-fired plants have also accelerated, especially in terms of contributing to acid rain.

While environmental aspects of hydro projects were first raised in industrialized countries, such concerns have now permeated to developing countries. An example is the present controversy over the Silent Valley project in South India. It is now mandatory in many developing countries to carry out environmental impact assessment (EIA) of all large hydroelectric projects prior to their construction. On the present trend, it is highly likely that those countries which still do not have the requirement to carryout EIA at present, will do so in the near future. The EIA requirement has already had a major effect on many projects presently under construction in that adverse environmental costs were identified in the planning stage and appropriate remedial measures were taken to alleviate them. Currently most multilateral and bilateral aid agencies insist that EIA of hydro projects be carried out prior to any aid is provided for construction. Regrettably, however the results are not integrated in the planning process. In other words, as required by the legislation of donor countries and policies of development banks, EIA is carried out primarily to satisfy legal and institutional requirements, without having any major impact on the design, construction and operation of the projects investigated.

As a general rule, small-scale hydro projects tend to be environmentally more favourable than large-scale developments, even when small dams have to be constructed. However, if environmental impacts are to be compared per KW of plant capacity or per KWh of output, this supposition is unlikely to be correct.

Future Hydro Developments

On a global basis, the largest unexploited hydroelectric potential currently exists in Africa, Asia and Latin America. The sites that are economically attractive and closer to centres of population are likely to be developed dirst.

There are, however, some major constraints. Probably the most important of these constraints at present involves the development of international

rivers (those shared by two or more countries) and inter-provincial rivers within countries under a federal system, e.g. India or Canada. Because of the inherent political, legal, and institutional complexites in such projects, these will be more difficult to develop than others. The magnitude of the problem can be realized by the fact that on a global basis there are 214 basins that are shared by two or more countries. Viewed from a different perspective, there are 44 countries where at least 80 per cent of the total area falls within international basins: 20 in Africa, 7 in Asia, 13 in Europe and 4 in Latin America. If the current experience is any indication, hydropower developments in international rivers are going to be time-consuming and frustrating affairs, and yet these are the rivers on which many potentially attractive development sites are located.

Country Reports

Hydropower development plans are to be found in most countries of the world. The status and future plans in selected countries throughout the world is given below:

Australia: Hydropower currently accounts for nearly 5 per cent of Australia's primary energy needs. It is unlikely to increase significantly in the future since the most suitable sites have already been developed.

Brazil: In theory at least, Brazil's electric power requirement could be fully met by the year 2000 by using its hydroelectric potential, estimated in 1979 at 213,000 MW, only 14 per cent of which is in use so far. More than 90 per cent of the potential has already been surveyed and analyzed. According to a well-established government programme, hydroelectric production will increase at an average rate of 11.3 per cent until 1995. The construction schedule in execution at present will increase hydropotential by 20,400 MW. Among large hydroprojects undertaken are Itaipu with 12,600 MW (jointly with Paraguay) and Tucurui with 3,960. It was planned to invest US $ 10 billion annually for this decade. Because of the present financial situation, it is somewhat unlikely to be achieved.

Canada: Hydropower currently supplies 24 per cent of total primary energy and constitutes more than 60 per cent of total electricity production. Provinces of British Columbia, Manitoba and Quebec rely almost exclusively on hydropower. Electricity consumption is expected to rise by 20 per cent during this decade. A number of hydro sites are available in British Columbia, Manitoba, Quebec and Newfoundland. Two big hydro projects are 10,200 MW James Bay in Quebec and 5,000 MW Churchill Falls in Labrador. The proposed Lower Churchill Development will add 2,300 MW capacity.

China: The country has a theoretical capacity of 680,000 MW, of which 370,000 MW could be economically exploited. Only 3 per cent of this potential has been exploited so far. The largest hydropower station in China at present is Liujiaxia in the upper reaches of Huang He, having 1.225 million KW installed capacity. Currently plans are underway for massive hydro development on the Chang Jiang (Known as the Yangtze River in the West) where it crosses from Sichuan to Hubei province. The power station will have a 2.5 GW capacity, twice that of Itaipu project. When completed, the Chang Jiang gorge power station would be exceeded in capacity only by the Grande Inge scheme planned on the Zaire River. Twelve large hydro plants, with a total capacity of 11 GW, are now in various stages of construction. More than 1,500 out of 2,000 countries have now built small-scale hydros, and these now provide some 40 per cent of their agricultural electricity requirements.

Egypt: With only one major river, the Nile, Egypt's hydro potential is limited. Nearly two-thirds of the Nile's potential has already been utilized with the High Dam at Aswan having 2,100 MW installed capacity. A pumped-storage project at Suez is being studied at present for meeting peak loads. The Qattera depression project, if implemented, will have an installed capacity of 600 MW.

Federal Republic of Germany: Approximately 90 per cent of economically useful hydro potential is already being utilized for electricity generation. The annual output of energy of these stations amounts to 18.7 TWh, with a total installed capacity of 4 GW. Future hydro development potential is severely limited.

France: Of a total economically useful potential of 72 TWh/year, nearly 62.5 TWh/year is operational and another 3.6 TWh/year will be available shortly.

India: Hydropower constitutes the cheapest source of power development in India. The total hydroelectric potential of the country is estimated at about 75,400 MW at 60 per cent load factor. Only 11 per cent of this total potential of 400 TWh has been developed so far, and schemes under construction will add a further 7 per cent. A significant percentage of unexploited potential lies in sub-Himalayan regions of northern and north-eastern India, in a difficult terrain and away from load centres. Such sites will be difficult to develop due to technical and economic problems.

Iraq: Currently 15 per cent of electricity generated comes from hydropower, and this is expected to increase to 36 per cent by 1990. Harnessing of the Tigris and Euphrates Rivers features prominently in the Iraqi plan. Among the largest plants is Samarra, having an installed capacity of 84 MW.

Kenya: The total installed hydroelectric capacity is nearly 450 MW. The main potential is concentrated on the Tana River, where 500-600 MW can b developed. The Kimbere project in the Tana Basin is expected to come on stream in 1986 and has a power potential of 130 MW. The Turkwell Gorge scheme in the Rift Valley, if implemented, will have a power potential of 120 MW.

Nigeria: As a petroleum exporting country, Nigeria's electricity sales increased during the 25-year period of 1951-52 to 1976-77 at an average annual rate of 18 per cent. The installed capacity of the hydroelectric station at Kainji that forms the backbone of the generating system is 760 MW. Two more hydropower plants are expected to come on stream shortly, 600 MW Shiroro scheme in 1984 and 540 MW Jebba scheme in 1985. Among the various hydro options being considered for the future is a 1,770 MW plant at Lokoja.

Sri Lanka: Hydropower plays the most significant role in generating electricity. During the period 1975-79, hydropower accounted for 98.3 per cent of electricity generated. In 1980, the figure dropped to 88.7 per cent. Approximately a quarter of hydroelectrical potential (1,600 GWh) has already been harnessed, and another quarter (1,500 GWh) is being developed under the accelerated Mahaweli scheme. Current plans are to harness the remainder (3,200 GWh) in quick succession in the 1990s.

Sweden: The northern part of Swedon contains substantial hydraulic energy. Currently, annual hydropower production amounts to 215PJ(60 TWh). Total technical hydro potential of the country has been estimated at 470 PJ(130TWh), of which 340 PJ(95TWh) can be developed economically at current energy prices. Because of restrictions placed on further development of large hydro power schemes by the Swedish Parliament to protect the natural environment, it is expected that the total production by 1990 will be around 240 PJ(65 TWh). The government, however, is promoting development of small-scale hydro (100 - 1,500 kW) through special economic incentives.

Thailand: The country has a potential to generate 17,304 GWh. The developed capacity at present is 1,270 MW, generating electricity at an average rate of 1,751 GWh in 1980. Small-scale hydro potential of the country is estimated at 1,066 MW of firm, dry-season unregulated power.

Turkey: With the South-eastern Anatolian Project (SAP), Turkey has embarked on an ambitious water resources development programme. When completed, SAP will generate 7,620 MW, which is four times the current hydropower generation. SAp consists of 13 large projects, the two most important of which are the Lower Firat Project and the Karakya Project, which will generate, respectively, 8.1 billion kWh and 7.5 billion kWh of electricity annually. Present plans are to complete construction of SAP by the year 2010.

USSR: In 1980, hydroelectric stations generated 183,000 million kWh, of which 102,600 million kWh was in the Asian part of USSR. Current estimates indicate that the total economic hydroelectric potential is 1,095,000 million kWh, of which 450,000 to 500,000 million kWh can be utilized in the foreseeable future.

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INDOOR AIR POLLUTION: A PUBLIC HEALTH PERPECTIVE

by John D. Spengler and Ken Sexton

Indoor air quality in nonoccupational settings has received relatively little attention from scientists, engineers, regulatory officials, and environmental groups, However, the available information suggests that elevated concentrations of some airborne contaminants are routinely encountered in indoor environments. Time-budget surveys have shown that most of us are at home more than 16 hours per day, with other indoor time divided between the workplace, commercial and public buildings, and transportation microenvironments (for instance, automobiles and subways).

Even if indoor air pollutant concentrations are low, they may make a substantial contribution to time-weighted exposures. The degree to which indoor air pollution represents a public health hazard has not been established. Nevertheless, concerns about health effects have prompted intervention at local, state, and federal levels of government to limit indoor exposures to sidestream tobacco smoke, asbestos, formaldehyde, and radon. In this article we discuss the scientific basis for recognizing indoor air pollution as a national health concern and the need for a coordinated policy to safeguard indoor air quality.

Contaminated indoor air is not new. Soot found on ceilings of prehistoric caves provides evidence of the high levels of pollution associated with inadequate ventilation of open fires. Elevated indoor pollutant concentrations continue to be a fact of life for people who live in impoverished areas and cook over open fires fueled by charcoal, wood, dung, Kerosene, or oil. Exposures to gaseous and particulate pollutants for these people greatly exceed measured pollutant concentrations in urban environments.

In industrialized countries, the more obvious indoor pollution problems have been known for decades. Minimum ventilation requirements, for instance, are a standard component of building codes to control odors and combustion by-products and reduce transmission of respirable diseases. However, the complex nature of indoor nonoccupational environments in technologically advanced nations (including synthetic building materials, energy-efficient buildings, unvented heating and cooking appliances, and cleaning and personal care products) makes possible widespread indoor exposures to a broad spectrum of airborne chemicals. Although many indoor pollutants (such as radon decay products and microorganisms) are below perception threshold, long-term exposures may cause increased rates of morbidity and mortality.

In the 10 years since Benson et al. reviewed the subject, a number of reports, symposia, and articles have been published which contain information on indoor contaminants with potentially negative health effects and on important indoor emission sources. Nevertheless, development of public policy to safeguard indoor air quality is hindered by a paucity of data on distributions of sources, building characteristics, daily activity patterns, indoor concentrations, exposure patterns, and health risks.

Basis for Concern

Increases in energy prices and in costs of new electricity-generating stations have encouraged individuals and institutions to seek alternative fuels and to reduce energy consumption. Because more than one-third of U.S. energy is consumed in buildings, efforts have been made to reduce energy use in the residential and commercial sectors. Common approaches include: adding insulation, reducing air-exchange rates, and fuel switching.

Increased sales of wood-and coalburning stoves and kerosene heaters suggest a national trend away from clean space-heating fuels such as electricity and gas. Sales of wood-burning stoves in the United States increased from fewer than 200,000 in 1972 to approximately 1.5 million in 1981. An estimated 3 million kerosene heating units were in use during the 1981-1982 winter, with projections of 8 million to 10 million by 1985. Emissions from these heating appliances contain toxic and carcinogenic particles and gases, yet indoor exposures and possible health consequences have not been evaluated adequately.

Because hospitals consume approximately 15 percent of all energy used in the commercial building sector, they have been target for energy savings. However, a panel of experts who explored the opportunities and constraints associated with relaxation of Department of Health, Education, and Welfare standards concluded that "the probable limiting constraint on ventilation is control of chemical contaminants. No information exists to adequately characterize the airborne chemical load in the hospital setting at the present time".

Reduced air-exchange rates in the presence of emissions from building materials and consumer products may adversely affect human health, welfare, and comfort. Urea formaldehyde foam insulation (UFFI), for example, has been shown to be a significant source of formaldehyde in some instances. Complaints, symptoms, and illnesses have been reported by occupants of buildings with UFFI, and its use has been abandoned in Canada. The Consumer Products Safety Commission recently proposed a ban on UFFI in the United States; however, this action is still subject to legislative and judicial review.

Mobile homes and prefabricated housing units are especially prone to indoor air pollution problems. They have lower mean air-exchange rates than conventional homes, air of smaller volume, use proportionally more materials containing volatile organic resins, and are more likely to use propane for cooking fuel. There were 3,722,000 occupied mobile homes in the United States during 1977 and about 250,000 new units will be shipped this year, an increase of 15 percent over the past 2 years. Mobile homes account for about 20 percent of the new housing market, and the number of mobile home occupants is expected to increase as restrictive zoning laws are phased out by many localities and states.

Another reason for concern is the growing number of building-related illnesses that have come to the attention of public health officials. The term "sick building syndrome" refers to health symptoms (for instance, irritation of mucous membranes, headaches, dizziness, nausea, diarrhea, rashes, and abdominal and chest pain) which affect occupants of a building. The Consumer Product Safety Commission has received more than 3000 complaints to date about exposures to contaminant releases from building materials. The National Institute for Occupational Safety and Health (NIOSH) conducted 115 investigations between mid-1978 and 1980 based on complaints from workers in nonindustrial settings who believed they were victims of building-related pollution. The New York City Department of Environmental Protection has received many complaints about indoor air pollution, despite the fact there is no established mechanism for receiving and dealing with consumer concerns about indoor air quality. Systematic investigations of building-associated illness are beginning, but local, state, and federal agencies often lack explicit authority, funds, and expertise to deal with this issue.

In summary, there is growing evidence that evaluation of indoor as well as outdoor exposures to air pollution is essential. If indoor exposures are not taken into account in epidemiologic investigations of air pollution, systematic and random biases may give rise to spurious conclusions (10 Total personal exposures are often better correlated with indoor than with outdoor concentrations. Those findings, along with concerns about reduced air-exchange rates and new indoor pollution sources, challenge the premise that costly controls on sources of ambient pollution are improving public health through reduction of human exposures.

Indoor Pollutants and Sources

Several Pollutants from indoor sources affect human health, Sidestream tobacco smoke, radon and radon decay products, asbestos fibers, fiber glass, formaldehyde,

combustion by-products (such as polycyclic aromatic hydrocarbons, nitrogen dioxide, carbon monoxide, hydrogen cyanide, and sulfur dioxide), aeropathogens, and allergens are associated with a range of problems from mild irritation of nasal and mucous membranes to irreversible toxic and carcinogenic effects.

The available evidence of toxicity, indoor concentrations, and number of people exposed suggests that some indoor air pollutants may constitute significant public health problems. The more important pollutants identified to date are briefly reviewed below.

Combustion by-products. Indoor combustion of fuels can be a source of Co, CO2, SO2, formaldehyde, hydrocarbons, nitrogen oxides, and a variety of particles. Numerous studies have reported elevated indoor levels of NO2,NO, CO, and CO2 in homes with unvented appliances. Depending on source use and air-exchange rates, long-term indoor NO2 averages can exceed the National Ambient Air Quality Standard (NAAQS) of 100μg/m3, even in areas where ambient outdoor values are 15μg/m3. Peak hourly NO2 concentrations between 200 and 700μg/m3 have been measured routinely in kitchens and other rooms of homes during conventional gas cooking. Elevated concentrations of NO2 or CO have been reported for homes and schools where kerosene heaters and unvented gas heaters are used and in skating arenas with gasoline powered ice-cleaning equipment.

Exposures to NO2 have been associated with toxicological effects including pulmonary edema, bronchoconstriction and increased infection rates. Some epidemiologic evidence indicates that increased respiratory infection in young children and adult males and lower polmonary function performance are associated with a history of exposure to gas stove emissions. Other studies failed to show significant effect associated with gas cooking.

Carbon monoxide from faulty furnances and attached garages is responsible for several fatal accidents each year Under typical use conditions, emissions from cooking appliances may raise short -term indoor CO concentrations 5 to 10 ppm. When a gas stove is used for heating, a common practice among urban poor in northern climates, concentrations of 25 to 50 ppm have been measured. Concentrations ranging from 25 to more than 100 ppm have been measured in iceskating rinks, apartments, and offices with attached or underground garages.

Carbon monoxide forms carboxyhemoglobin (COHb) in the blood and inhibits oxygen uptake. It is not known at present whether there is a threshold for adverse effects from oxygen deprivation due to COHb. Recent work indicates

that exercising adults with angina pectoris are sensitive to COHb concentrations as low as 1 percent. Community air pollution and indoor exposures to combustion by-products or sidestream cigatrette smoke can raise COHb in non smokers to 2 to 3 percent.

National Ambient Air Quality Standards have been promulgated for CO and NO2 and emission controls for mobile and stationary sources are required by legislative mandate. A limited number of personal exposure studies showed significant correlations between exposures and indoor concentrations. The evidence suggests that many, if not most, exposures to NO2 and CO occur indoors and are therefore not represented accurately by outdoor monitors.

Tobacco smoke. Tobacco smoke is discussed separately for several reasons. First, nearly everyone is exposed at one time or another to tobacco smoke. Although 33 percent of the adult population regularly smoke cigarettes, this figure does not necessarily characterize the population of exposed children. For example, epidemiologic studies in the United States have shown that the percentage of children living in homes with one or more smokers ranged from 54 in Tucson to 76 for a middle-income community in St. Louis.

Second, more than 2000 compounds have been identified in cigarette smoke, many of which are established carcinogens, irritants, and asphyxiants. And third, there is increasing evidence that passive exposures to tobacco smoke may affect respiratory health.

Tobacco combustion indoors contributes to concentrations of respirable particles, nicotine, polycyclic aromatic hydrocarbons, CO, acrolein, NO2, and many other substances. The resulting concentrations vary widely, depending on the frequency and amount of smoking, air-infiltration rates, air-cleaning devices, and air-distribution systems. Measurements in bars, restaurants, airplanes (smoking section), buses, conference rooms, and offices indicate CO and particulate matter concentrations of 2 to 35 ppm and 10 to 1000 µg/m3, respectively. Analysis of respirable particle samples collected in 80 homes over several years indicates that a "pack-a-day" smoker will contribute approximately 20 µg/m3 24-hour indoor particle concentrations. Where two or more heavy smokers resided in a house with low air-exchange rates, the 24-hour NAAQS of 260 ug/m3 was also violated.

While the health effects of smoking on smokers have been studied extensively, the health effects on nonsmokers have received far less emphasis. Many substances in cigarette smoke are irritants, and conjunctival irritation, nasal discomfort, cough, sore throat, and sneezing have been noted in nonsmokers exposed to cigarette smoke.

Measured changes in heart rate, systolic blood pressure, COHb, psychomotor functions, and small airway dysfunction have also been reported in nonsmokers who are exposed to smoke.

Most studies of the effect of parental smoking on respiratory health in children show an association with reported respiratory morbidity in children, especially during the first 2 years of life. An association between the number of cigarettes smoked per day by the parents and respiratory symptoms in children has been a consistent finding. However, these relations do not always appear independent of parental symptoms, socioeconomic class, or smoking habits of the children. Some investigators found an association between tobacco smoke exposure of nonsmoking wives whose husbands smoke and increased lung cancer rates.

The National Academy of Sciences stated in its report on indoor pollutants: "The constituents of tobacco smoke are well-documented as hazardous, the prevalence of population exposure is very high, and there is an increased incidence of respiratory tract symptoms and functional decrements (decreases) in children residing in homes with smokers, compared with those homes without smokers. These considerations and recent evidence of increased lung cancer rates among non-smoking women living with smoking husbands have led us to conclude that indoor exposure to tobacco smoke has adverse effects. Public policy should clearly articulate that involuntary exposure to tobacco smoke ought to be minimized or avoided where possible."

Radon and radon decay products. Radon is a radioactive decay product of radium-226. Radium, a natural trace constituent of rock and soil, is found in building materials made from earth crustal components. Radon-222 is a gas with a half-life of 3.8 days. It decays through polonium-218, lead-214, bismuth-214, and polonium-214 before reaching lead-206, a stable isotope. These decay products are solids and can attach to aerosols, which may become embedded in the lungs and irradiate surrounding tissue. It is usually radon gas which diffuses into indoor air from the ground, building materials, or well water. Higher concentrations are typically measured in basements, crawl spaces, and homes with low air-exchange rates.

Radon and radon decay product concentrations have been measured in conventional and experimental homes in several states. Typical radon concentrations range from 0.01 to 4 pCi/ liter. In "energy-efficient" house, levels exceeding 20 pCi/liter have been reported. Concentrations ranging from 0.1 to 27 pCi/liter were measured in 52 conventional houses in maryland. Integrated samples during the winter in 4000 Swedish homes averaged about three

times the concentrations reported for Maine homes and 20 to 30 times the concentrations reported for homes in California and Texas.

Concerns about adverse health effects of indoor exposure to radon decay products are based on the higher incidence of lung cancer observed in uranium miners. Although indoor home exposures are thought to be considerably lower, risk is proportional to exposure and the number of people exposed is large. Recent reviews of epidemiologic studies of radon and lung cancer in miners estimate that lifetime risks range from 21 to 54 to 1000, deaths per 10^6 working level months (WLM). For the range of inhome radon exposures typically recorded 0.04 to 0.8 WLM, excess lung cancers in the United States have been estimated to be as high as 10,000.

Microorganisms and allergens. A large variety of biological materials is present in indoor environments. Inhalation of biological aerosols discharged by people and animals is a primary mechanism of contagion for most acute repiratory infections. Tuberculosis, measles, smallpox, and staphylococci are known to be transmitted by air ventilation systems in schools and hospitals. Air-cooling equipment, cool-mist vaporizers, humidifiers, nebulizers, flush toilets, ice machines, and carpeting can incubate and distribute bacterial aerosols indoors. Legionnaire's disease (Legionella pneumophila) and humidifier fever are well-known examples of air-conditioning-relat-ed bacteria.

According to the National Health Survey, respiratory ailments (predominantly upper respiratory disease and influenza) account for more than half of all acute conditions, including ilnesses and injuries. The incidence of respiratory conditions is just under one per person per year, and they typically restrict activity for 4.5 days. Higher incidences are observed among younger children and the elderly. Considering the loss of time from work and school, as well as medical costs, the impact of indoor cantagion is probably enormous. There is a lack of data with which to evaluate the relation between infection and ventilation rates. If the primary mechanism is by contact rather than inhalation, the prevalence of respiratory infection may be unaffected by changes in ventilation.

Pollen, molds, mites, chemical additives, animal dander, fungi, algae, and insect parts are known indoor allergens. Sources of indoor allergenic materials include pets, detergents, humidifier and air-cooling fluids, growth of molds and fungi on surfaces, and insects that live in dust and vents. Temperature and humidity conditions are important for many indoor aeroallergens. For example,

house mites flourish at temperatures around 25°C and relative humidities above 45 percent. Because high humidity favours the growth of molds and fungi, tightly sealed buildings in humid climates are more prone to allergenic problems.

Reduced ventilation and increased use of untreated recirculated air may increase concentrations of microorganisms. Prolonged exposure to some chemicals and antigens can cause sensitization. Therefore, reduced fresh air in buildings might lead to increased rates of infection and allergy. However, little is known about sources, concentrations, and survival rates of many aeropathogens indoors.

Formaldehyde and other organic compounds. Building materials (plywood, particleboard, and so on), furnishings (carpets, draperies), and some types of foam insulation contain formaldehyde resins, the most common of which is urea formaldehyde. Excess formaldehyde in these products can be released over a considerable period. Outgassing rates are higher for new materials and are directly influenced by humidity and temperature. Although few longitudinal studies have been done, the half-life for formaldehyde emissions is approximately 4.4 years. Unvented gas combustion and tobacco smoking are other sources of indoor formaldehyde.

Indoor formaldehyde sampling has been conducted principally in locations where higher concentrations were suspected. Measurements in Denmark, the Netherlands, the Federal Republic of Germany, Sweden, and the United States have shown that formaldehyde concentrations often exceed 0.1 ppm. In 23 Danish homes the average formaldehyde concentration was 0.5 ppm and the range was 0.07 to 1.9 ppm. In response to occupant complaints, formaldehyde concentrations in more than 200 mobile homes in Washington State were measured and were found to range from 0.03 to 2.4 ppm. Similar finding were reported for mobile homes in minnesota and Wisconsin. Formaldehyde concentrations of 0.1 to 0.5 ppm have been measured in conventional homes and schools without obvious sources. Concentrations in excess of 0.1 ppm appear to be common in homes insulated with UFFI.

Adverse effects from formaldehyde may result from inhalation, ingestion,or contact.The compound showed mutegenic activity in a variety of microorganisms and produced nasopharyngeal carcinoma in laboratory rats and mice Chamber studies with humans showed eye discomfort in the concentration range 0.1 to 0.4 ppm, while residential exposures as low as 0.02 ppm were associated with tearing and eye irritation. The fact that in -home responses occur at lower exposures may reflect a broader spectrum of sensitivity in in the population at large, increased sensitivity due to prolonged low-level exposures,adaptation of volunteers in

the chamber studies to elevated formaldehyde concentrations, or effects of other irritants present in indoor air. At concentrations of 10 to 100 ppm, formaldehyde exposures can cause lower respiratory irritation and pulmonary edema.

Formaldehyde effects on the nervous system are not well understood, although psychological and neurophysical effects have been reported. The results are difficult to interpret, but suggest that formaldehyde levels of 1 ppm can affect the central nervous system, Effects include subtle changes such as short-term memory loss, increased anxiety, and slight changes in adaptation to darkness.

A variety of other organic contaminants have also been identified in indoor environments. People emit bioeffluents such as acetone, butyric acid, ethyl and methyl alcohol, and other acids and alcohols. Combustion of wood, kerosene, and tobacco produces polycyclic aromatic hydrocarbons. Application of pesticides can release chlorinated hydrocarbons or organophosphate compounds. Personal care products, cleaning materials, paints, lacquers, and varnishes generate chlorinated compounds, acetone, ammonia, toluene, and benzene. Health risks associated with indoor exposures to this diverse group of chemicals have not been investigated adequately.

Asbestos fibers. Because of the widespread use of asbestos-containing products in ceiling tiles, floor tiles, pipe insulation, spackling compounds, concrete, and acoustical and thermal insulating material, there is a large potential for public exposure. Acute exposures to asbestos and glass fibers cause severe skin irritation. A variety of neoplastic diseases, with latency periods of 15 or more years, have been associated with asbestos exposures. Increases in lung cancers, pleural and peritoneal mesotheliomas, and gastrointestinal tract cancers have been linked to occupational exposures. Several studies have shown increased mesothelioma rates among persons living near asbestos-production facilities and shipyards and among family members living with asbestos-exposed workers.

Airborne fiber concentrations determined by NIOSH standard methods range from zero during normal activities outdoors and in schools, offices, and dormitories to more than 100fibers per milliliter during disrupting contact maintenance to ceilings. Unless the materials is extremely friable, which is rare, asbestos exposures are likely to be episodic and therefore difficult to evaluate by random monitoring. Electron microscopic examination of air samples revealed values ranging from nearly zero outdoors in many U.S. cities to about 2000 ng/m3 in a New Jersey school during custodial activities. Current asbestos standards include an Occupational Safety and Health Administration (OSHA) standard of 2 fibers per milliliter and a recommended NIOSH limit of 0.1 fiber per milliliter.

Although few measurements of air concentrations are available, it is clear that house, schools, and office buildings can become contaminated. Risks to the general public are unknown since only exposure-effect data from occuptional settings are available. However, the possible synergism with other contaminants, particularly cigarette smoke, and the severity of the potential health consequences justify steps to limit exposure to asbestos.

Most (85 percent or more) of the asbestos in use is immobilized in strong binding material. However, if this material is deliberately or accidentally disrupted, asbestos fibers can be released. Because the material can be found in easily accessible places and in ventilation systems, there is a potential for fiber release as a result of maintenance, renovation, negligence, or vandalism. In 1978, the U.S. Environmental Protection Agency (EPA) banned sprayon application of asbestos-containing substances, except those in which the asbestos fibers are encapsulated with a bituminous or resinous binder during spraying to reduce friability after drying.

Controls

Workable and effective control strategies must be based on an understanding of several pertinent factors. First, contaminant characteristics need to be assessed, including: concentrations, reactivity, physical state, and particle size if applicable. Second, emission source configurations should be taken into account. Are discharges continuous or intermittent, are they point or area releases, and do they originate primarily indoors or outdoors? Third, the nature or exposure response relations must be considered. Are individuals to be protected from long-term exposures to low concentrations or periodic short-term exposures to peak concentrations? Finally, the type of indoor enclosure is important. Some ameliorating measures are more suited to private residences than to public buildings, or to new, as opposed to existing, structures.

Identified indoor pollution control methods fall into five general categories: Ventilation; source removal or substitution; source modification; air purification; and behavioral adjustments to reduce exposures (avoidance). These classifications are not mutually exclusive and effectual strategies might use combinations, such as ventilation, source removal, and behavioral changes to reduce nonvoluntary exposures to tobacco smoke.

Public Policy Issues

Realization that indoor air pollution may represent a public health hazard presents policy-makers with familiar

questions: Is the problem serious enough to warrant official intervention and, if so, what public actions are most appropriate? Healthful indoor air quality-what it is and how to achieve it-is not yet well understood, and scientific data on exposures and associated health effects are lacking. Nevertheless, the mounting evidence of elevated indoor contaminant levels suggests that government efforts to safeguard citizens' health and safety may be justified.

Government response so far has been piecemeal and complaint-oriented. In some cases, such as asbestos, many different federal agencies have jurisdiction over portions of the problem. For other pollutants, like microorganisms, combustion by products, and organic emissions from building materials, responsibility is not clearly defined. No overallstartegy exists to provide a coordinated well-managed approach to ensure adequate indoor air quality.

Historically, government measures to redress environmental pollution have been taken when identified pollutant hazards receive abundant attention in the media and sufficient public awareness is generated. With the possible exception of antismoking groups, no organized. constituency has developed to champion the cause of clean air inside buildings. The absence of a group lobbying for healthful indoor air quality removes much of the political urgency normally associated with environmental problems. As results of ongoing research become available, it is likely that public pressure for official intervention will build and legislators will have more incentive to take action.

A more structured and institutionalized approach is advocated by many professionals involved with this issue. Suggestions have included: coordinated interagency research; consolidation of federal responsibility within one agency; amendment of the Clean Air Act; and granting of authority to states to regulate indoor air quality. A bill (HR-6323) was introduced in Congress during 1982 to appropriate funds for the Environmental Protection Agency to study the problem and recommend remedial actions.

As Sexton and Repetto pointed out, it is essential to realize that a fundamental difference exists between indoor and outdoor air. Outdoor air is a "public good" in the sense that members of a community breathe basically the same ambient air. No rational individual would undertake the task of cleaning up the air over Boston, for example, since his or her share of the benefits would be much smaller/ cooperation suffice, since those who refused to contribute could not be excluded from enjoying the benefits of reduced pollution. Similarly, in the absence of regulations or legal liability, no pollution source would spend enough on abatement, due to the difficulty of collecting from beneficiaries. The rationale for government regulation of outdoor air pollution has focused on the issue that those who suffer the effects are not compensated, nor is their interest in cleaner air readily effective in influencing polluters.

The situation is quite different for some indoor environments, especially private residences. Both the costs and benefits of pollution control are internalized within households. If occupants foul the air in their own home, they are forced to breath it. If they attempt to improve its quality by increasing ventilation or installing air-cleaning devices, they bear the costs and enjoy the benefits. For some contaminants, such as tobacco smoke, odorants, and water vapor, benefits are readily recognizable through improvements in perceptible air quality and reduction of corrosion, soiling, and molds. For pollutants that are harmful to human health, but below perception thresholds, benefits will include reduced health risks due to lower exposures.

Creation of a regulatory framework for indoor air quality poses special policy issues which bear directly on choices about appropriate public responses. Certain aspects of nonworkplace environments are now subject to government ordinances, including residential and commercial building codes, health regulations, safety rules, and fire ordinances. However, this form of intervention is not necessarily optimal or even desirable. Although there are similarities between indoor and outdoor air, the complex set of regulations comprising the Clean Air Act should not automatically serve as a guide for indoor control strategies. Setting strict indoor air quality standards would almost certainly be expensive because of the costs associated with monitoring and regulating approximately 100 million buildings in the the United States. Perhaps the most serious impediments to the regulatory approach are public antipathy toward this form of intervention and problems associated with enforcement. The diversity of nonoccupational indoor environments needs to be considered before practical and cost-effective control strategies can be designed and implemented.

It must also be taken into account that households are already making decisions about their own air quality. Promulgation of regulations might or might not improve those decisions. To determine the appropriateness of regulatory intervention it is necessary to do more than compile information about pollutant concentrations, human exposures, and associated health hazards. It is equally important to obtain information about individual perceptions of indoor air quality, public awareness of health risks, and the extent to which better information influences consumer choices. Commonsense precautions by building occupants may well prove to be the most effective and least expensive control measures. For this reason, the effectiveness of public information programs in promoting behavioral adjustments that will reduce personal exposures to air pollution needs to be evaluated (for instance, voluntary segregation of smokers and nonsmokers inside buildings).

In the development of effective public policy, the responsibilities of different sectors in society that have a stake in this issue should be emphasized. There are important distinctions between the responsibilities of individuals, building designers, contractors, operators and owners, professional organizations, product and material manufacturers, and government.

Recommendations

The issue of indoor air pollution and its effect on public health is complex. Yet because society has been slow to recognize the importance of healthful indoor air quality, the information we have is fragmented, anecdotal, and often contradictory. As with other environmental contaminants, strategies for reducing risk to exposed populations must be based on defensible exposure-response relations. In this way, the costeffectiveness of various control options can be evaluated on the basis of reductions in population exposures.

Several major issues are involved in decisions concerning the need for public action to deal with indoor air pollution. First, the role of government may depend on the degree of "publicness" of a particular building. The rationale for government intervention is stronger for public buildings (such as hospitals) than private residences. Government responsibility may be different for occupational and nonoccupational settings and for existing and planned buildings.

Second, dissimilarities between indoor emission sources may be important. Many contaminants in indoor environments (tobacco smoke, combustion by products) result from human activities, while others (radon, formaldehyde) are less dependent on the activity patterns of occupants. Behavioral adjustment (such as prohibiting smoking in public places or using hood ventilation during cooking) may be the most effective and inexpensive way to control pollutants arising from discretionary actions. For pollutants not directly related to human activities, such as those emitted by soil, tap water, building materials, and furnishings, stricter building codes, simple air cleaning devices, or sealants might be required.

Third, some indoor pollutants, such as tobacco smoke, are perceptible to most people, and individual action to reduce personal exposures may be predicated on sensory stimuli. Other pollutants are below perception thresholds (radon, microorganisms, asbestos, CO, NO_2, and so on). Consideration of voluntary and nonvoluntary risks is important

for policy decisions. Development of simple warning devices could provide individuals with information on which to base decisions about the appropriateness of remedial measures. Such actions could reduce the need for government intervention to mitigate public health risks.

Fourth, it is necessary to specify whether building occupants are to be protected from chronic exposures to low levels of pollution or short-term peak exposures. If long-term exposures are considered important, then reductions in total human exposures to air pollution should be the goal. If short-term exposures are critical, then efforts should be focused on identifying peak concentrations and protecting the population at risk (for instance, limiting CO exposures for building occupants who use gascooking stoves for space heating).

Fifth, policy-makers must balance the benefits of energy conservation measures (for instance, reduced ambient pollution from fossil-fueled power plants) against the costs of deteriorating indoor air quality. Determining the essential coponents of healthful indoor air is a fundamental part of this process.

Sixth, if it is decided that public intervention is needed, a regulatory approach should not automatically be adopted. Policy alternatives such as economic incentives, better definition of legal rights and liabilities, public information programs, and expanded administrative efforts based on existing legislation might be more appropriate for control of indoor environmental hazards.

Because data from several studies indicate indoor exposures to some pollutants may represent significant health risks, official efforts to define the magnitude and extent of public health consequences seem justified. However, the future of public efforts to deal with indoor air pollution in nonoccupational environments is uncertain. Adequate fundaing is not currently available. Given the present regulatory climate of limited government instrusion and increasing reliance on free-market economics, it seems unlikely that programms focusing on indoor air pollution will be initiated in the near future. We believe that an overall strategy should be developed to ensure a coordinated, well-managed investigation of indoor air pollution exposures and their health consequences. In combination with efforts to define the problem, control options and policy alternatives should be evaluated.

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TECHNOLOGY DEVELOPMENT

by Ralph E Gomory

Basic scientific research, with its tradition of open communications in an academic, or academic-like, setting, is widely described and commented on in the public press. Many college graduates have some idea of how scientific research is conducted by having seen at work the professors who are the back-bone of the scientific professions. The history of science and, more recently, even the sociology of science are established fields of scholarship.

Technology development, on the other hand, occurs mostly in industrial settings, and many fewer people get to see it. It is usually not well described in the public press or in the history that people learn. It is therefore not surprising that the evolution of technology development is often confused with science in the public mind.

Yet this poorly understood, invisible process of technology development is what we all depend on for improvements in our material daily life, for the transmission to other countries of knowledge that we hope will raise their standards of living, and, to a considerable extent, for our own country's strength and progress.

Technological Evolution and Breakthroughs

Technology development is much more evolutionary and much less revolutionary or breakthrough-oriented than most people imagine. It is important to relize that series of evolutionary steps in technology, together amounting to a large improvement, is just as revolutionary as a breakthrough. That this is the normal course of technology development may be illustrated by two historical examples. These examples are given here not only to illustrate this abstract point but to furnish concrete instances as a basis for a real understanding of technology development.

Steam Engine

The first is the steam engine. The popular notion of the development of the steam engine includes the story of how James Watt was in his mother's kitchen, the kettle boiled., steam came out, and Watt realized the tremendous power of steam and later invented the steam engine. This story has nothing to do with

reality, and Watt had nothing to do with kettles. The true origin of the steam engine is very different and much more interesting.

The history of the steam engine may be considered to start in about 1680 with the famous Dutch physicist Christian Huygens, who was trying to develop an engine based on gunpowder. It was recognized at that time that there was power in gunpowder or in fire which, if it could be harnessed, would furnish another source of energy. This could then supplement existing energy sources of the time, which were animal power (for example, horses turning treadmills), wind power (windmills), and water power.

Huygens did not attempt to harness the explosion of gunpowder directly; his method, which was more sophisticated than that, was to explode a little gunpowder in a cylinder, under a piston. The piston was already up, and the idea was that the explosion would create a vacuum and the weight of the atmosphere would then push down the piston. Although it was a rather sophisticated approach it did not work, because the explosion left behind residues and did not create a sufficient vacuum.

However, Denis Papin, an assistant of Huygens, conceived of a way to use steam to create a vacuum. His idea was to boil water over a fire (thus capturing something from fire), put the steam in under the piston, close the bottom of the container, and let the steam cool so that it would condense. This would create a vacuum and down would come the piston. In about 1690 Papin built a model, a small-scale engine of this type, and it worked.

In England, about 8 years later, Thomas Savery made the first full-scale working steam engine. He had a number of problems with it. Savery did not use atmospheric pressure. He used steam to drive the piston, and he used it at high pressure. Unfortunately, the mechanical technology of that time was not up to full use of the design. The machine worked but had troubles with high-pressure steam, and its use was restricted by the pressures that the boilers and piping could withstand. It was used mainly for low water lifts to pump water for water-wheels and supply water to large buildings. But this design fell into disuse.

The next step was due to Thomas Newcomen, a plumber. Indeed, one of the morals of this history is that the people who did this work were plumbers, wheelwrights, and instrument makers. Newcomen came up

withthe first reliable and widely used steam engine. It was basically a blown-up version of the Papin engine. Water was boiled in a boiler and the steam was put into a cylinder. A spray of cold water was applied to the cylinder to cool the steam and create a vaccum, which in turn forced down the cylinder. Then the piston was lifted back up, and the cycle was repeated. The Newcomen engine became important in early 18th-century England, where it was used largely for pumping water out of coal mines. This was an important application; many coal mines were unusable unless they were pumped out all the time. In fact, many mines were abandoned because people could not keep the water out. It was a life-and-death problem for the coal miners. The Newcomen engine found a niche where it could survive, and for 20 or 30 years the technology consisted mainly of Newcomen engines pumping water out of coal mines - until it took the next step forward.

Before describing the next step and its effect, a number should be introduced: the 'duty', a measure of the goodness and efficiency of engines. This was the number of millions of foot pounds of work an engine could do by burning one bushel of coal. The duty of the Newcomen engine was about 4. A rough estimate of the work a horse could do for the same cost falls somewhere between 14 and 24.

The next step was taken by John Smeaton, who, around 1767, made a better engine and raised the duty to 7 to 12. Invention, it should be stressed, did not play a major role in this improvement. Smeaton knew how to bore cylinders better. The best mechanics of that time could bore a cylinder for a steam engine only so accurately that one could insert a worn sixpence between the piston and the cylinder. This was why they used the atmospheric engine rather than high-pressure steam - much less steam escaped.

Finally, around 1775, James Watt appeared. The real Watt was an instrument maker, and he got into steam engines because he was given a small model of a Newcomen engine that did not run and was asked to fix it. While working on the problem he realized that energy was being lost by heating the cylinder with steam and then cooling it to condense the steam. Watt solved the problem by supplying the engine with a separate condenser. The cylinder remained hot; the condenser remained cool. This raised the duty of the engine by about another factor of 2.

Later in his life, Watt introduced a two-stroke engine, with the atmosphere driving the piston one

way and steam driving it the other. That was worth about another factor of 1.5. The duty was raised by these innovations to between 24 and 35.

In the period 1800 to 1830, engines with more than one cylinder were introduced, and by that time the mechanical technology permitted the use of high-pressure steam. With these innovations, the duty went up by another factor of 2 or 3, from about 37 to nearly 100. The small technology that for 20 or 30 years existed mainly in the business of pumping out coal mines had been transformed, through a series of evolutionary steps, into the energy source that changed the world.

Two points in this story are characteristic of the development of new technologies. One is the cumulative effect of small steps (note that mythological history has erased that and replaced it with a single breakthrough on the part of James Watt); the second is the significance of the niche (in this case coal mines) - the special place in which a technology may survive, even though it is not yet ahead of other technologies of its time in more general applications.

Computer

The second example I would like to discuss is the computer. As a concept, the computer existed in reasonably well developed form in the first half of the 19th century. More than 100 years ago, Charles B Babbage, a well-known English inventor conceived the idea of a programmable computer. However, the technology of his time-cogs, wheels, and axles - did not permit the easy realization of such an instrument and there was little demand for computation outside astronomical tables. The beautiful idea that Babbage worked out was not realizable in the circumstances of 100 years ago. It was much later that vacuum tube technology made computers feasible while the impetus for large-scale computing was provided by World War II. The combination of technology and motivation gave rise to the first generation of vacuum tube computers; the EN IAC, EDSAS, and EDVAC, the Whirlwind, the Institute for Advanced Study machine, and many others. There was an early period in which many technologies competed for the role of memory - for example, storage tubes, cores, and thinfilm memories. Finally, the transistor, invented at Bell Laboratories, came along and swept the whole development into a totally new phase.

The transistor was a real breakthrough, it was the result of a long buildup of understanding of solidstate physics and then a rather sudden transfer

of that knowledge into a new area - the area previously populated by vacuum tubes. Once it got going, this development, like the steam engine, was in the hands of practitioners. It was mentioned before that the evolution of the steam engine was conducted by mechanics, plumbers, and so on. Similarly, the transistor came out of fundamental scientific knowledge, but its continued development was in the hands of semiconductor engineers, where today it is evolving rapidly. In 1968 memory chips held 16 bits, 4 years later 1,000, and today 64,000 to 128,000. There is every reason to expect 256,000 bits per chip in the next few years, and so on into the indefinite future.

The evolution of the transistor has also spawned the microprocessor, which is often described as a breakthrough, but which can be regarded as such only in the sense of an application breakthrough. The development of the microprocessor was foreseeable. Every year more and more circuitry could be put on a chip. Looking a few years ahead, one could realize that an entire processor, or the central processing part of a computer could be put on to one chip. Finally it happened, and when it did there was an enormous number of applications for it. That was the main element of surprise.

The arrival of the microprocessor was unavoidable, given the rapid evolutionary progress of transistor technology. I am stressing the evolutionary part, and that is the state that computer technology is in today. I think that the computer is the analogy in our time of the steam engine, in its technical evolution and in its revolutionary impact. If I seem to be down on breakthroughs, it is because I think they are both rare and extremely important. I think we do have them. I do not like to see the confusion that occurs when that name is used for what is just the next step in technology, because it obscures the true nature of much important technical progress that is evolutionary. The transistor itself was a genuine breakthrough. Recombinant DNA and its application to chemical processes are breakthroughs. These are not the next steps in a technology but are the introduction of something quite new.

The transistor was the result of long, patient, and mainly undirected basic scientific work that led to a sufficient understanding of solid state physics to make it possible. The knowledge that led to its introduction in a field where only vacuum tubes had been before came out of another field. Similarly, the atomic bomb was not the evolutionary outgrowth of explosives but represented the introduction of knowledge

about the structure of the nucleus into the field of weaponry. Similarly, recombinant DNA - should it prove to be successful in chemical processing - will be the introduction into a new field of the accumulated know-- ledge about the fundamentals of molecular biology.

Real breakthroughs do occur; they are rare and stunning events. The more common course of technological evolution is steady, year to year improvement, and when that is rapid and persistent, the results are just as revolutionary.

Characteristics of Science and Technology

Armed with these histories of the steam engine and the elements of computer technology, we can raise questions about science and technology. How do they interact? The two examples cited indicate, as many have observed, that it is a two-way street and that science and technology affect each other, and are affected by each other, in more than one way. Of course, we are accustomed to the idea that science contributes to technology. The early history of the transistor is an example of the introduction of scientific knowledge into technology with stunning results. On the other hand, the development of the steam engine was the work of practical men gradually adding improvements driven by the needs of application. This persisted until the 1830's when the need to make still better steam engines and to understand them stimulated the development of the science of thermodynamics. Technology in that case drove fundamental science. This is happening today; the computer is driving computer science. Furthermore, the evolution of technology makes better scientific instrumentation possible, and this can be a major factor in the advancement of science.

What are some of the characteristics of science and of technology? Science can be thought of a large pool of knowledge, fed by the steady flow from the tap of basic research. Every now and then the water is dipped out and put to use, but one never knows which part of the water will be needed. This confuses the funding situation for basic science, because usua - lly no specific piece of scientific work can be justified in advance; one cannot know which is going to be decisive. Yet history shows that keeping water flowing into the pool is a very worthwhile enterprise.

Scientific research, which feeds this pool, has its own culture and its own imperatives, which are very different from those of technology. It is motivated by the desire to satisfy curiosity, as opposed to the imperative of technology to get out a working product.

In the United States, science (in contrast to technology) is highly valued. Scientists are esteemed mor. than the practitioners of technology. Science is primarily university-oriented and to a considerabled extent government-funded. The principal citizens of science are Ph.D.'s It is reasonably represented on the national scene. All but one of the Presidents' science advisers of the past(Frank Press, H. Guyford Stever, Edward E. David, Jr., Donald F. Hornig, George kistiakowsky, and Jerome B. Wiesner) come from the world of science but represent both science and technology. The current relative prestige of science and technology is peculiarly American. The situation varies a great deal from country to country, and in some countries it is considerably different from that in the United States.

Technology is different. It is manned primarily by engineers, not Ph.D.'s. It is usually industry-oriented rather than university-oriented. It is driven by applications and products rather than by the imperatives of science. However, perhaps the most important point about technology is that it tends to be very complex.

Because of its complexity, developments in technology are sometimes hard to predict. The problems and the advantages of evolving new technologies are often not obvious. In the early days of the transistor, germanium was selected as a transistor material because it allows electrons to move more rapidly than they do in silicon. This seemed to promise much higher speed, But, in fact, it turned out that silicon almost completely supplanted germanium because it naturally grew on its surface a layer of oxide that protected the finished chip. That practical consideration far outweighed the apparent advantage of germanium. Today we have almost entirely silicon technology.

Another example is Josephson technology, a proposed new computer technology, which relies on superconductivity and some variations on it that occur only in certain metals and at temperatures near absolute zero. We understand all these complex phenomena, but they are not the problems with this new technology. The actual problems are more mundane, but much harder and of the following sort.

The computer itself is complicated. Large computers have to be repaired during their lifetime, partly because things break down and partly because things they were designed wrong in the first place (no one has

yet designed a large computer completely right). In the course of its lifetime, a large computer has to have the capability of being repaired, let us say 300 times. If you were repairing one of the machines that depends on superconductivity, you would have to take the cooled elements out of their cooling bath to fix them 300 times - and that means that all of those elements would have to be able to withstand the expansion of coming up to room temperature and being cooled off again 300 times without anything going wrong.

The phrase "Without anything going wrong" masks another level of complexity. The computer might have 7 million basic elements. Those 7 million elements would all have to be warmed to room temperature and cooled again 300 times with a minimum of failures. If one failure occurred every time the computer was warmed, then after cooling the computer would have to be warmed up again right away to repair that one failure, which would probably cause another failure, and the result would be a totally inoperative machine. The difficulties in this technology, therefore, are not really in understanding the difficult phenomena: they are in making very tiny elements that can expand and contract 300 times and in creating an assemblage of 7 milion of those elements that will almost never have even one thing go wrong with it.

In addition, a machine like a computer has to be manufacturable, and this introduces a whole new set of extremely difficult requirements before all of the small components will work.

To illustrate the requirements related to manufacturability, I will discuss the magnetic bubble device, in which a small thing called a "bubble" moves from one tiny piece of metal to another. For the device to work, the two pieces of metal have to be the right distance apart, or the bubble will not jump the gap. The bubble has to travel within a layer of material (garnet) that must be the right thickness, and it is moved by a magnetic field that provides a particular force. The practical problem is to manufacture these tiny devices with such precision. The two pieces of metal are never exactly the same distance apart; they may be 10 or 15 percent off. The thickness of the layers may vary by 5 percent; the magnetic field is never completely uniform. The result is that the design must have a tolerance window that will permit the device to work even though the distance is 15 percent off, the thickness is 5 percent off, and the magnetic field may be 8 percent off. In addition, all of these things vary with temperature, so that the design also has to take into account a certain temperature range.

In new technology development, even if you are looking at a working device, you may be looking at something that needs a couple of years of redesign work before it is manufacturable, because it has to be designed so it can withstand all those changes and still work.

Cultural Factors

In dealing with technology, things are sufficiently complex that much is done by rule of thumb and not by precise knowledge. Many factors enter in; some of them are even cultural. (I am using the world culture here only to indicate a general set of habits of a group of people. There is no implication that this culture is unchangeable; in fact, it is very changeable.) Let us consider an example. A complex part was being made, It went through a large number of process steps. Only about 6 percent of the parts that came out at the end worked. That was not nearly enough because, with the cost of the whole process, a 6 percent yield made the parts too expensive. On the other hand, no one could find anything seriously wrong with the process. So the engineers moved in and stood where the production people had been, and they carried out the process in the hope of finding out where it was going wrong. They never found anything wrong with it because they got a yield of approximately 60 percent when they did exactly the same thing. Eventually it became clear that the people who had been doing the processing simply had not been trained to be precise enough. Sometimes they put a screwdriver in a hole that was later used for precise positioning. In handling a part they sometimes made little nicks and scratches on it or touched it with their hands. Later, things would not adhere to the surface that had been touched. The accumulated effect of those things made the difference between 6 and 60 percent.

Technology is culture-dependent in other ways. Cultural factors such as attitudes toward financing (long-term versus short-term goals), attitudes toward carelessness and small mistakes (quality), and the presence or absence of the famous NIH (not invented here) syndrome (it is hard to get someone else's idea into your laboratory) have a tremendous influence on technological progress.

The best example of culture interacting with technology is, of course, Japan. I refer not to modern Japan, but to the Japan that was opened up to the world by Commodore Perry in 1854. The same country, in 1905, using Japanese-constructed battleships and naval guns and a combination of the most complex technological instruments of that period, destroyed

the Russian fleet in the battle of Tsushima. This remarkable transformation from a feudal state to one that could create the most technically advanced machines of its time in a span of 50 years is, to my knowledge, unparalleled in the history of technology. That culture has continued, and Japan is once again making tremendous strides. Other countries, for reasons we do not really understand, have had much more trouble assimilating technology. China, for example, which many people consider to have been culturally superior to Japan for thousands of years, has never under any kind of regime been able to make that kind of technological progress. Great Britain, which started and led the industrial revolution, is today strong in science but weak in technology. There is no simple connection between scientific mastery and technological leadership. When the United States and Japan are compared on a scientific level, the United States is well ahead. But on a technological level, it is quite another story.

Technology Transfer

This picture of technology as a complex and even culture-dependent process bears on a number of things, including security, in the sense of secrets, and technology transfer, in the sense of trying to get a technology to someone else in the same country or in other countries.

It is hard to keep a simple idea secret. The idea, for example, of having a separate condenser for a steam engine can be expressed in one sentence. It is hard to keep that one sentence a secret. On the other hand, it is hard to transfer the full complexity of a technology. There is too much. Those who are not technologists in the same field cannot even be sure which details matter. So simple things are hard to keep secret, and complex things like technology are hard to give away.

Let me add a caveat, which is that everything depends on the receptor to whom the secret or the technology is to be given. If the receptor knows very little, he can do very little even with the simple idea, because he cannot generate the mass of detail that is required to put it into execution. On the other hand if he knows a great deal and is capable of generating the necessary details, then from just a few sentences or pieces of technology he will fill in all the rest. That is why it is hard to transfer technology to the Third World and very hard not to transfer it to Japan.

Technology, more than science, moves forward in a world in which time and expense are extremely important. An experienced colleague of mine, Robert Henle, told me that there is a saying that in technology you never run out of ideas, just out of time. I saw that borne out some time ago when we were trying to get a new printing technology ready. It took longer and longer, and finally we stopped the effort and substituted a conventional technology in order to get the product out. People working on the new technology said that they still had a lot of ideas about how to fix it, and that was true. We had not run out of ideas, but we had run out of time.

New technologies are generally expensive because they are not yet refined. Therefore they often cannot compete with existing, in place technology, which has been refined. That is where, in the case of the steam engine, the coal mines came in. Often new technologies depend on finding some small use that can keep them in existence while they improve. If they do not find it, they will never reach their full potential, because no one will spend the money to keep them going.

This, incidentally, is an important role that military procurement fulfills, even though it is a small part of the commercial marketplace, because military requirements often place extreme demands on quality and capability that can only be met by new technologies. Those technologies are thus kept going and are given a chance to grow to maturity.

Scientific Knowledge

All kinds of fundamental issues arise in the course of technology development which require the most advanced scientific knowledge or even new scientific knowledge for their solution. The effect of cosmic rays on computer memory is example. To understand what happens and to prevent loss of information from the memory requires knowledge of the detailed interaction of these particles from outer space with the crystalline matter of the transistors and the ability to trace the effects of this interaction into the memory. So we need directed basic research - that is, work done at the most fundamental level, but intended to get certain practical problems solved. This should not be confused with the important pool-filing activity alluded to earlier.

Organizational Problems

Bringing scientific knowledge to bear on technology is not easy. Inventions or solutions to problems occur

when the knowledge of a need and the technical or scientific knowledge to cope with that need finally come together in one head. Everything else is just a means to that end. Those means often become elaborate, except in a very small organization.

Small organizations have their own problems. They usually do not have the technical skill to solve fundamental problems unless they are set up specifically for that purpose. In most large organizations there is an elaborate apparatus that, in one way or another, tries to take knowledge of a need and translate it into a clear-cut technical or scientific problem. The need for more speed in computers in the marketplace may be translated into saying to a person with a knowledge of ceramics, "I need a new ceramic with a lower dielectric constant." This long process of translation usually calls for some organizational apparatus. However, organizations tend to develop a life of their own. The individuals or small groups whose scientific knowledge you rely on and to whom you try to translate your needs may be more interested in ceramic science than they are in computers. The fact that your requirements are written down does not remove the difficulty. Written documents are often worse, because without a dialog between individuals it is difficult to convey exactly what is meant and what is really important. These problems are not easily dealt with. In fact, it is hard to overestimate the diluting and distoring effects of long chains in organizations, long chains of command, or long chains of information transmission.

One way of overcoming these effects is to have people move around Researchers should know what development is like; developers should know what their product is used for. In that way, these difficulties can be short-circuited to some extent. Another stratagem is now and then to talk to someone at the bottom of the organization and get an exact and detailed account of what he is doing. An executive may think, for example, that his organization is investing in navigation, only to learn that it is investigating turtles laying eggs. That may sound funny, but there is a real connection.

One way to study navigation is to study animals that exhibit remarkable navigational ability. An example is the sea turtle. It is difficult to study sea turtles in the water, so people start by studying sea turtles on the shore when they come out to lay their eggs. That may well be what is going on in the organization, and it may be necessary to decide between producing a new navigational device in a few years or contributing to the basic pool of scientific knowledge, which experience has shown to be useful in the long run.

The usual problems of an organization are made more acute when it is technologically oriented. In an average organization, usually a hierarchical one, there is an implicit assumption that the people with the power to decide, the people in certain positions of the hierarchy., also have the knowledge to decide. In a sales organization, for example, the veteran salesman has first been a sales manager; he knows how to run a branch office, then he runs a group of branch offices, then he runs a region, and so on. He understands reasonably well what it is all about.

In a technological organization, it is often the case that the person with the power to decide does not have the detailed technological information needed to make a decision. These complications can be dealt with. A special task force is often formed at this point. This is an adhoc group of trusted people with the technical knowledge to investigate the question at the right level of detail and report their reasoning and conclusions to the person in charge.

Morale and attitudes are also important in dealing with this difficulty. Key technical people must feel free to make their views known. The person in charge should also have key technical people, not usually those who report directly to him, whom he feels free to consult. All this is easier in an organization with enthusiasm and a shared sense of purpose and direction.

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WHAT MAGIC FORMULA FOR SUCCESS?

Japan's success in world markets is the envy of the West. Where does science come in the success story ?

How and why has Japan succeeded so well ? And where will it end? Those are the questions that send people from the West flocking to Tokyo and, occasionally, even into the hinterland. The motive is mostly economic, for in the past decade most industrialized countries in Western Europe and North America have been frightened out of their wits by the apparently endless stream of technical innovation in consumer electronics from Japan, put on sale at prices competitive with and often lower than the bare costs of manufacture elsewhere. Motor cars and cheap high-quality steel (still flowing from Japanes production lines) may have kept politicians and others awake at night, but were not so obviously the products of advanced technology. So is the torch of progress, the leadership of the free world or some other such figurative emblem, about to pass to the Western Pacific? That is why there has been such a surge of interest in Japanese science and technology. And that explains why journalists from the West now commpete with delegations of businessmen and government officials bent on begging the Ministry of International Trade and Industry (MITI) to organize a voluntary export quota on the latest electronic product and even, still, motor cars.

Nature has made this fashionable pilgrimage for a somewhat different and more self-interested purpose. Readers know that many of the journal's contributors work in Japan, but may not be aware that close on ten per cent of each week's print-run goes there, now (at last) by air. So Japanese science is as much a part of a single constituency as, in a wider sense, science itself cannot be partitioned by national boundaries. If, as reports suggest, Japanese practitioners have worked some kind of miracle, they deserve congratulations, while other readers may wish to know in more detail what they are about. This is the spirit in which an earlier survey of science in Japan was carried out.(Many of the conclusions then remain unaltered.

Briefly, the most vivid impression of basic science in Japan is what everybody would expect: some is exciting, some worthy and some downright pedestrian. This was the case ten years ago, as it always has been elsewhere. Nobody should be surprised at that. In 1972, however, it seemed proper to complain that the government of Japan was shockingly neglecting the needs of university researchers. Resources are now improved, but only patchily; and the government is still unwisely mean.

Technology is different. Optimism abounds. The small army of engineers graduating each year from the

universities seems uniformaly to believe there are no obstacles between feasibility and production. Success feeds on itself, and has spread outside the technical community. Casual acquaintances ask for admiration of "our technology". And well they might, for it has kept them afloat since the oil shock exactly ten years ago. And city crowds at least are visibly more prosperous. But not everything the engineers have touched has turned to export earnings. Even so, there is no obvious reason within technology itself why fields now strong-electronics for example- should not be further strengthened, leading to what has quaintly been called "world domination" in some areas. "So what?" is the only level-headed reply. As the following pages show, Japanese technology is not strong accross the board, while the benefits of a rational division of labour between nations are as real as when Adam Smith defined them (intranationally) 250 years ago. And anything might go wrong. In basic science, the uncertainties are intrinsic; defining problems is one battle, solving them another, but then the job is done. In technology, the most worrying uncertainties are extrinsic-political and economic stability, social change and mere accident. That Sakhalin Island (once Japanese) turns out to be so close will give many people pause.

Both Japan and its competitors therefore need to understand the reasons for the successes of the past few years. A few Western myths are easily disposed of. The belief that Japanese technology rides on the back of cheap labour is belied both by the statistics on wages in manufacturing industry (but young people do less well than in the West) and by the continousimprovement of labour productivity, more than 8 per cent a year since 1960 or three times as fast as in the United States. The charge that Japanese successes are simply imitations of Western innovation is similarly mistaken. Much technological innovation succeeds if it leads to an improvement of only a few per cent in some performance characteristic. Japanese companies do not disparage such innovations, but see them as a way to please customers, increase sales and perhaps make a fortune. They have paid for patent licences like men. Perhaps manufacturers in the West should follow suit. But who can say that the electrostatic microphone or the device that allows joggers to hear Beethoven's Ninth while running are anything but ingenious exploitations of a market?

The biggest Western myth is that the boom has been engineered by MITI, supposed for these purposes to be an omnipotent manipulator of companies' intentions, not to mention the value of the yen on the foreign exchanges. The ministry is, on paper at least, no more influential than say, the Department of Commerce in the United States.

What MITI does is to spend modest sums of its own money on stimulating collaborative research projects by industrial companies, stopping short at the awkward stage where exploitation is on the cards. (The cost of the much-vaunted fifth generation computer at Y23,000 million over eight years is not very different from the £400 million spent over five years in Britain alone on collaborative research.) Japanese companies roar with laughter when it is suggested that MITI has an influence on the pattern of their development. The need to compete with each other is too urgent to wait on the bureaucratic timetable.

But MITI can be blamed for its part in the non-tariff barriers to trade of which Japan's trading partners loudly complain. Tariffs, entry taxes on imports, are not very different from those elsewhere, while the complainants agree that many of their past failures in the Japanese market owe much to its complexity and obsession with quality. But there is also a system whereby imports are inspected, consignment by consignment, for compliance with Japanese quality and safety standards as they arrive. There is also a system of import quotas, chiefly for agricultural products, which has had the United States for years complaining that Texas could supply the whole of Japan with beef if only the trade were free. The complaint ignores the political difficulties any Japanese government would face in deciding to put its farmers out of the beef business.

Complaints about export prices are more substaintial, but again may stem from ignorance. The dependence of Japanese manufacturers for their capital on fixed-interest bank-loans, and the tradition of life-long employment which makes staff costs inflexible, imply that plants must be made to produce as great a volume of goods as can be managed. The practice seems to be to regard the cost of export sales as related somehow to the marginal cost of production. If exports are subsidized, the Japanese customer and not MITI meets the cost. The only long-term remedy is to sell imported goods competitively on the Japanese domestic market.

These are the myths and half-myths about the success of Japanese technology. The reality is different. Japan's post-war successes have come in several distinct waves. How many Japanese now remember their pre-war dependence on the export of silk? Between 1950 and 1970, the most obvious component of technological innovation was modest (but not necessarily unspectacular) improvement of other people's technologies. If larger ships are likely to be cheaper (per tonne) to build and operate, why not work out the technology of building ships in the million-tonne range? If a large part of the cost of making steel is that of paying for the smelting plant, why not arrange that a furnace can operate more quickly?

But from the beginning, there were qualitative innovations-by 1960, for example, the Japanese optical industry had won a much-envied reputation for the high quality of its lens design and found that its cameras would sell on quality, not just on price. And even now, when the steel industry everywhere is in the doldrums, Japanese companies are among the chief suppliers of high-quality spun-steel pipes as used in the oil and gas industries, a handy hedge against fluctuations in the cost of oil imports. Motor vehicles with two wheels have made their way in the world by being technically more advanced than their competitors but Japanese cars, at first competitors for established industries on the grounds of cost (or productivity), have more recently begun to command attention for being cleverly designed. And it was Mazda, the Japanese manufacturer, that in the 1960s took up the Wankel rotary engine after manufacturers in the United States and Europe had declined to take the risk.

The more recent growth of the electronics industry, quantitatively spectacular, does not yet amout to a technological revolution (but may yet trigger off a social revolution). Four ingredients seem to matter-superb design, accurately anticipating users' needs, efficient and immaginative roduction engineering and careful quality control (so that products sold are usually found to function). The trick is to make the possible happen.

Why should these tasks be apparently easier in Japan than elsewhere? The only persuasive explanation involves people (including technologists) but not technology as such. First, as the pages that follow illustrate, those in charge of the direction of development appear to have recognized that junior colleagues probably have the most to contribute to innovation. Second, the general enthusiasm for improvement is infectious. Third, there is a widespread sense of personal responsibility, in research laboratories and on production lines, for seeing that allotted tasks are done successfully. And corporately, Japan now has a wealth of experience to show that the most sure route to riches from technical improvement is to be best. To be first helps, but is not essential.

This is where the economic climate of Japan is crucial. New projects mounted with such ambitious aims are bound to be expensive. The investment of the companies seeking to make in biotechnology in what is, for practical purposes, a self-training programme is a vivid example of the scale on which resources are being invested in innovation. Financial stability and a high savings ratio obviously simplify the process. While there are now signs of the emergence in Japan of the kind of venture capitalism that tends to back innovation in the United States, for some time to come the willingness of large strong companies to branch out in new directions will be essential for the continuing change of pattern in Japanese industry.

In many ways, this has been the most striking feature of the "boom". While the growth of the economy has been steady, at least with the exception of 1974, the pattern of production has kept changing. Seiko, the company best known for its quartzwatches, seems now to have recognized that it cannot continue to make them as cheaply as similar watches are made in Hong Kong, and is seeking other technologies to exploit, scientific instruments for example. From now on, as in the past decade, Japanese industry may be having to rebuild its productive base at intervals of a decade or so. Here again, it will have to accomplish this with the life savings of the Japanese people.

No wonder that Japan as a whole is asking whether the task will be as easy now that Japan is in the forefront of technology. Opinions differ, but it is striking that even in the fields in which Japan is strongest, electronics for example, there are surprising gaps in what Japanese corporations in aggregate have to offer. At first sight, for example, it would have been expected that Japan would be strong in the development of software for computing machinery. Teams of loyal programmers developing the software for a digital switching system for the telephone network would seem to fit ideally with the Japanese way of working. Yet NTT, the telephone company, says that the software may have to be imported to operate its new two-way broad-band communications system. More probably, suppliers such as Hitachi are right when they insist that the gap will soon be bridged; the mystery is that NTT should have left this crucial task so late.

Much the same is true of Japan's computer industry proper. Japan's three leaders in the field, Fujitsu, Hitachi and NEC(short for Nippon Electric Company) have in the past 10 to 15 years been quick to follow the path of development in the United States. They and the other members of MITI's fifth-generation computer consortium (Mitsubishi, Toshiba and Oki) now have on offer a range of computing machinery comparable technically with what is available in the United States. Moreover, the first three manufacturers have judged it worthwhile to develop large capacity machines comparable with the US Cray and Cyber (Control Data) mainframe computers, capable of some hundreds of millions of arithmetical operation a second and used chiefly in defence command and control systems and applications such as weather forecasting.

What seems so far to be lacking in Japan's computer industry is the exuberance to be found in other sectors of the electronics industry when manufacturers sense that they have some substantial market in the palms of their hands. The usual explanation is that hardware has outstripped software, but the underlying difficulty may be more general- that in the field in which the technology is changing quickly and in which the ultimate users of computers are rarely able to specify with clarity just what they want to buy,

manufacturers are not being helped to define their strategy by the loud and confident response of the market they have come to expect in other fields.

None of this, however, justifies the present wave of introspection in Japan about the underlying creativity of Japanese technology. Both in industry and government, the proposition is put like this: Japan has hitherto been an imaginative imitator of technological developments elsewhere in the world, principally in the United States. And while everybody knows that climbing Everest for the first time is the hardest task, in which false starts and expensive mistakes are bound to crop up time and time again, what if Japanese technology is somehow deficient in creativity, unable to pick out on the horizon of the future the Everests worth tackling?

This line of argument has provoked a great flood of anxious nail-biting. Some blame the educational system for its regimentation of its students. Some gloomily wonder why only four Nobel prizes have been awarded to Japanese scientists since the beginning of the century, asking whether that may not be a sign that Japanese society may be deficient in imagination. To outsiders, this whole train of thought is a self-indulgent irrelevance, based on a view of technology that is, in any case, false. People talk as if there is somewhere a hidden map of the technological future, and as if the question has now become that of knowing which parts of it will be coloured in by Japanese companies and their research people.

The mistake is to forget that technology is not an end in itself but (in high-sounding language) a means of satisfying social needs or (more down-to-earth) a servant of the market. The self-indulgence centres on the supposition that Japanese technology is already comprehensively competitive with that elsewhere (which is plainly not the case, for example, in aircraft manufacture or in the whole field of medicine). And the introspection about Japan's supposedly poor showing in the tally of Nobel prizes is an irrelevance because it should be clear to everybody that the most immediate explanation (if one is required) is the relative neglect of basic science both by the government and, more significantly, by students embarking on higher education, who still march predominantly into engineering.

Whether the years ahead will see this imbalance between academic science and engineering corrected is far from clear. It is, however, plain that nothing much will be accomplished without a radical change in the relationship between the government and the universities, necessary on other grounds and now long overdue. In deeply conservative Japan, the prospect that there will be such a change is far from bright.

This does not necessarily imply that technology as such will be held back, at least in the short run, but simply that the hankering after a richer intellectual setting in which Japanese technology can be embedded will remain unsatisfied.

Another Japanese tradition - the notion that a young person joinning a company should expect to stay with it for the rest of his life - is probably another brake on the capacity of Japanese technology to throw up new projects. As things are, the successful companies are fully conscious of the need for flexibility, and claim to be able to redirect the objectives of their technical people without much difficulty. Obviously it helps that those concerned feel themselves to be part of a team whose success will determine their own personal prosperity. But there must be limits to what personal dedication can accomplish. There is a strong tradition in Japanese technology of recruiting senior research people ((directors of laboratories for example) from government laboratories from which people are usually required to retire at 55 (and may leave earlier), but the relative immobility earlier on must be a drag.

Meanwhile, the ingredients of past success in technology will persist. The widely advertised robots now working away in Japanese manufacturing plants will no doubt multiply and prosper, but the wonders of the past three decades derive from the personal qualities of the army of engineers that created the boom. Their technical flair, their willingness that it should be harnessed to agreed objectives within the group or corporation in which they work, their zeal for work and their enthusiasm for success are the true foundations of Japan's technology.

So the best guess is that the torrent of success (marred from time to time by glaring mistakes) will continue into the future. Those elsewhere who nurse the conceit that it should be possible to outsmart their Japanese competitors by launching on the world ideas that are somehow cleverer overlook the detail that has gone into what Japan has done. Japanese steel companies dominate the market for steel pipes because Japanese metallurgists and engineers have worked out how to roll pipes of high quality, consistently and on a large scale. The same is true in consumer electronics. Chagrined competitors have no choice but to follow the Japanese model but more thoroughly. And that, not the balance of payments is the most striking measure of success: the boom is a model of how to do things that others must emulate if they, too, are to succeed.

(Nature, 305, 5933 (Sept. 29-Oct.5, 1983) pp.355-58)

MAINTAINING SCIENTIFIC PRIMACY

by Frank Press

The eagerness of both parties to increase support for scientific research has for the scientific community, an element of deja vu. The increased funding is highly welcome, as a needed corrective to chronic underfunding in several areas and recent budgetary damage to others. But, if such support is not to prove evanescent, the scientific community must be articulate about the dynamics driving the need for funding increases. One such dynamic is the cost of national primacy in science: the ever-rising expense of maintaining a frontier position in scientific research and of advancing at the margins. Instrumentation, the level of training, and computational demands all scale upward in cost and complexity as research becomes more demanding. Many of the concerns in this country related to the health of science - its support and its institutions - stem from the pressures of being at the scientific frontier, at the top of very slippery climb.

Other countries are now climbing that slope. Japan and France, for example, have both acknowledged a limit to dependence on derivative science for their future technological capacities. They and other nations are already contesting our primacy in various fields of scientific research, and even more will do so. We ought to welcome the competition, for as long as we see to our own house we will gain greatly from the scientific advances of other nations.

Such an argument is seemingly contradicted by the current, and proper, concern with U.S. capacities in global technological competition. However, while basic research is a component of technological competition in global markets, it is not the most critical element. Moreover, the scientific endeavor should transcend the momentary frictions of such competition. It is - or should be - a global binding agent, uniting all cultures in the common quest to understand nature and to improve the human condition.

If the United States (or any nation, for that matter) is to gain from intensified scientific competition, the essential requirements are open communication of science and the resolve to incur the costs of maintaining general excellence in basic research. Regarding open communication, the Matthew principle applies: those that have the most to give have the most to gain. The strength of American science ensures our capability to benefit from progress in any field elsewhere.

The budget now going through Congress will be a major factor in retaining scientific strength and, therefore, in gaining from the advances of other nations. But beyond the program increases - essential to enriching the substance of science - we need to examine the institutions of science. For example, public and private research universities - the "home of science" in the United States - are, with the rest of the economy, suffering from financial pressures. Overall, the patterns of state, federal, and private support continue to be volatile, the embedded costs of graduate education are rising, and some of the usual subsidies for graduate education may no longer be available.

Other elements underpin our leadership in world science, such as the health of American education. There now is a national awakening to our potentially disastrous weaknesses in science and mathematics education. A number of bills are in Congress, and the budget for fiscal year 1984 contains new initiatives in science education. In the past, the nation's concern with education was fleeting. We need to emplace enduring programs.

The United States will face difficulties in staying at the frontiers of science. But if we maintain the excellence of our research, we stand to gain a great deal from the first-class research of other nations. Required of us is a commitment to keep our research institutions strong, to ensure stability in funding basic research, and to insist on open communication of science among all nations.

(Science, 220, 4597 (May 6, 1983) p.559)

Perspectives in Biotechnology

by M.S. Swaminathan

Biotechnology is a broad term and has been defined in different ways. The European Federation of Biotechnology defined this branch of science as "the intergrated use of biochemistry, microbiology and chemical engineering in order to achieve the technological application of the capacities of microbes and culture cells". A recent offshoot of biochemistry is genetic engineering which involves gene splicing and recombinant DNA cloning. Tools of biotechnology have been used for centuries for producing wines, beers, vinegar and various alcoholic beverages through fermentation as well as in food processing drug manufacture and detoxification of human and animal wastes.

Establishment of the National Biotechnology Board

What is new about recent development in biotechnology is the use of knowledge about the interior of cells to direct and manipulate the products they make. Recombinant DNA technology as well as cell fusion and tissue culture techniques have opened up possibilities for directing cells to produce what we desire. This has placed biotechnology at the forefront of both basic and applied sciences. The practical applications are just beginning to emerge, although premature claims and expectations have been current for several years now. Tissue culture has been described as the botanical equivalent of the laser, in that there are more potential applications than originally conceived. The decision announced by the Prime Minister on January 3, 1982 at the last Science Congress held at Mysore to set up a National Biotechnology Board has hence been a wise and timely one. This Board now functioning under the Chairmanship of Prof. M.G.K. Menon is serving as an apex policy guidance and coordinating mechanism and has developed both short and long term plans for promoting the growth of biotechnology research and applications in India.

The National Biotechnology Board has chosen problems in agriculture, energy, health, environment and industry for priority attention. The areas of work to be promoted include genetic engineering, photosynthesis, tissue culture, enzyme engineering, alcohol fermentation and immunology. For achieving results of practical value, a critical mass of interdisciplinary effort will be needed with adequate facilities for careful and replicable experimentation. The potential hazards associated with recombinant DNA technology need to be kept under surveilance, although no serious problems have arisen so far. Vigilance is prudent since we are still in the early stages of using these techniques in higher organisms. At the same time it should be noted

that biotechnology techniques provide at present much safer methods of working with highly pathogenic microorganisms. The cloning of the foot-and-mouth virus of cattle has for example greatly enlarged the ability to work with this virus.

Recent Applications:

(a) Monoclonal antibodies:

The discovery of the hybridoma technique in 1975 has opened up new vistas in immunology. This involves fusing myeloma (cancer) cells with antibody producing cells from an immunised donor. The hybridoma resulting from this fusion has the capacity to multiply rapidly and indefinitely in culture and produces an antibody of pre-determined specificity, referred to as monoclonal antibody. This technique is of immense value in the diagnosis of ifections diseases in human, animal and plant populations. Among plants, this technique may have application in India in the case of Citrus tristeza virus coconut wilt disease prevalent in Kerala and rice virus diseases. Hence, the National Biotechnology Board could accord priority to establishing a Monoclonal Antibody Centre for producing antibodies for use in diagnostic and epidemiological studies of selected diseases affecting human, animal and plant populations in the country.

(b) Vaccines:

Monoclonal antibodies and recombinant DNA technology have opened up new possibilities in the speedy production of effective vaccines. An advantage of genetically engineered vaccines is the use of a single or small number of components rather than the entire infectious organism. The antigen is separated from the infective component of the virus thus avoiding the risk of spreading infection during the manufacturing process. Also, it may be possible to prepare vaccines against pathogens for which vaccines cannot be readily manufactured by conventional methods, as for example in the case of human infectious hepatitis. The National Biotechnology Board will have to identify carefully the diseases for which genetically engineered vaccines should be prepared, based on a careful assessment of the comparative advantages of the new techniques. For example, although vaccine production for the foot-and mouth (FMD) disease in cattle has been in progress for many years using conventional techniques, residual infectivity in inadequately inactivated vaccines has been a cause for the occasional recurrence of the disease. Recombinant DNA technology provides a method of preparing an absolutely non infective product.

(c) Energy:

Among areas which need added attention are (1) biomass production and utilisation, (2) fermentation and alcohol production, (3) biogas technology and (4) energy plantations around all major towns and cities.

(d) Biological Nitrogen fixation:

Immediate benefits are likely to result from:

1. Optimising nitrogen fixation by Cyanobacteria, blue green algae, Azolla-Anabaena complex etc.

2. Development of Rhizobial strains tolerant to different soil and environmental stresses.

3. Improved technology for the production and distribution of efficient strains of Rhizobium.

4. Development and extensive planting of fast growing leguminous shrubs and trees.

Work on the conversion of cereals into nitrogen fixing plants is in progress in several countries. The specificity of susceptibility to Rhizobia in leguminous plants is due to their capacity to produce lectin proteins that direct bacterial invasion of root tissues. If the leguminous lectin and leghemoglobin genes can be moved to the cereal plants, the host range of Rhizobia can be extended. Due to many technical problems, this line of research is not likely to result in success in the near future.

(e) Tissue Culture:

Cell and tissue culture techniques are already in use for (1) breeding stress tolerant varieties in crops like rice, (2) clonal propagation of forest and fruit tree species, (3) disease elimination in tapioca and other vegetatively propagated plants thereby facilitating international germplasm exchange and (4) gene transfer over sterility barriers. Other applications include the production of androgenic haploids in plants through anther culture and the fusion of protoplasts. The work already in progress in India on the induction of flowering in bamboo (Delhi Univer-Botany Department) and clonal propagation of coconut (Central Plantation Crops Research Institute, Kasargod), needs to the strengthened and intensified immediately. The aim should be the breeding of annual varieties of bamboo and the speedy multiplication of healthy coconut palms occurring in gardens severely infested with the root wilt disease. Similarly, cereal tissue culture techniques for identifying cell lines with tolerance to salinity and soil constraints need to be effectively used.

Protoplast fusion provides an opportunity for producing hybrids in cases where sexual hybridization is unsuccessful. Opportunities exist in Azolla for undertaking this pathway of breeding.

Conclusions

Only concentrated and continous efforts undeterred by set-backs and failures will help to achieve the desired goals. Genetic engineering techniques in higher plants and organisms are not likely to result in dramatic improvements in the foreseable future. While modification of single cells is the end of research in microorganisms, it is just the first step in higher plants. In higher plants, cells must be modified, multiplied and regenerated into a whole plant. The modified traits must be manifested in the whole plant and retained in succeeding generations. We need more basic information in the fields of gene function and cell differentiation. Also, more research on the development of cloning vectors, capable of replicating both in plant and bacterial cells are necessary. Support to basic research is hence vital for success.

During the 1980s, improved food production will come largely from the use of the already available materials and technologies. The new technologies, while being by and large scale neutral with reference to their applicability to farms of varying sizes, are not resource neutral since modernisation of agriculture involves the increased use of purchased inputs. While biotechnology research may some day enhance the resource neutrality of technology, the only immediate method of producing food for the growing population is the effective and timely delivery of essential services like credit, seed, fertilizer etc., to enable small and marginal farmers to take to the best available technology. The gap between potential and actual yields is high in most farming systems even at currently available levels of technology. Therefore, there is need for stepping up efforts in technology transfer, while at the same time the National Biotechnology Board should foster and support intensive and carefully planned research in biotechnology for generating scale as well as resource neutral technologies in agriculture, animal husbandry, fisheries and forestry. In addition, full advantage should be taken of the possibilities for producing Insulin and other compounds of medical interest through genetic engineering techniques. Research as applied to industry deserves equally strong support, particularly with reference to industrial microbiology and fermentation technology. In this way, socio-economically relevant blends of traditional and emerging technologies can be developed.

(Everyman's Science, XVIII, 2 (1983) pp.48-51)

Human Insulin from Recombinant DNA Technology

by Irving S. Johnson

(Summary)

Human insulin produced by recombinant DNA technology is the first commercial health care product derived from this technology, Work on this product was initiated before there were federal guidelines for large-scale recombinant DNA work or commercial development of recombinant DNA products. The steps taken to facilitate acceptance of large-scale work and proof of the identity and safety of such a product are described. While basic studies in recombinant DNA technology will continue to have a profound impact on research in the life sciences, commercial applications may well be controlled by economic conditions and the availability of investment capital.

(Science, 219, 4585 (Feb.11, 1983) pp.632-37)

PROSPECTS IN PLANT GENETIC ENGINEERING

by Kenneth A. Barton and Winston J. Brill

(Summary)

The functional expression of a novel gene in a genetically engineered plant has not yet been reported. One major barrier in movement toward this goal is our limited understanding of the molecular bases of gene expression. Attempts to establish genetic engineering as a practical facet of plant breeding are also complicated by the fact that genes for most important plant characteristics have not yet been identified. However, the benefits to be gained from all aspects of plant improvement are stimulating research into both the development of plant transformation technology and the isolation and characterization of genes responsible for valuable traits. As scientists develop greater knowledge of plant molecular genetics, we can expect to see practical applications in such diverse areas as improvement of plant nutritional quality, decreases in fertilization requirements, and increases in resistance to environmental stresses and pathogens.

(Science, 219, 4585 (February 11, 1983) pp. 671-76)

CROP GERMPLASM CONSERVATION AND DEVELOPING COUNTRIES

BY D.L. Plucknett et. al

(Summary)

Loss of the genetic diversity of some of the world's crops has accelerated in recent decades, with many crops becoming increasingly susceptible to diseases, pests, and environmental stresses. A global network of gene banks has therefore been established to provide plant breeders with the genetic resources necessary for developing more resistant crops that will enable farmers to maintain high yields. Most of these gene banks now store the germplasm of only the major crops such as cereals, potatoes, and grain legumes. Cultivated varieties of these crops are conserved as well as wild species that might otherwise become extinct. Tropical cash crops such as bananas and coconuts are also important food crops in many Third World countries, and more effort needs to be made to conserve the germplasm of these crops as well as of other important plants such as plantation crops, medicinal herbs, and fruit and timber trees.

(Science, 220, 4593 (April 8, 1983) pp. 163-69)

BACTERIAL, VIRAL, AND FUNGAL INSECTICIDES

by Lois K. Miller, et. al.

(Summary)

Microorganisms that are pathogenic to insects provide a wealth of biological material that can be exploited by humans to control insect pests. Innovative applications of a few such entomopathogens are found throughout the world, but widespread commercial production of microbial insecticides awaits further studies of the biology, ecology, and pathogenicity of the agents. Genetic engineering techniques may be used to increase the virulence of these microorganisms, as well as to make them more tolerant of physical and chemical conditions and perhaps to broaden their host ranges. The use of microbial insecticides could decrease our dependence on chemical pesticides.

(Science, 219, 4585 (Feb. 11, 1983)pp. 715-21)

CHOLESTEROL-HEART DISEASE LINK ILLUMINATED

New findings explain how blood cholesterol levels are controlled and how to lower them substantially in persons at high risk of heart disease.

by Gina Kolata

The relationship between cholesterol and heart disease has, until recently, eluded scientific explanation. It was known that extremely high concentrations of cholesterol in the blood can - by themselves - cause heart disease. It was known that cell surface receptors for a protein that carries cholesterol in the blood somehow are necessary for the control of blood cholesterol levels. But no one knew how blood cholesterol concentrations are controlled nor any logical way to substantially lower blood cholesterol in people at very high risk of heart disease.

This state of ignorance is now changing, thanks in large part to the discovery of an animal model for a human disease of cholesterol metabolism. Not only do researchers understand how cholesterol levels are controlled but they are, at last, well on their way to answering the fundamental questions of the cholesterol-heart disease hypothesis: Does a lowering of blood cholesterol actually prevent heart disease? And how does cholesterol cause heart disease in the first place?

Until about 3 years ago, scientists were stymied. They knew that cholesterol alone can cause heart disease because patients with homozygous familial hypercholesterolemia, a genetic defect, have six to eight times the normal level of cholesterol in their blood and invariably develop heart disease. These people usually have their first heart attacks in childhood and die of heart disease by the time they reach their early 20's.

Even people who are heterozygotes for familial hypercholesterolemia and so inherit one normal gene as well as the hypercholesterolemia one have heart disease problems. Their cholesterol concentrations are two to three times higher than normal and, although they number only 1 in 500 in the population, they account for at least 5 percent of all heart attacks in persons under age 60.

Not only were these people with familial hypercholesterolemia identified, but the exact nature of their genetic defect was known. They lacked functional

cell surface receptors for low density lipoproteins (LDL), which are the fundamental carriers of blood cholesterol to body cells.

Yet, say Michael Brown of the University of Texas Health Sciences Center in Dallas, "We knew that humans with familial hypercholesterolemia have this receptor defect and we knew it blocked the removal of lipopro - teins from the blood. But we couldn't analyze human tissues to see which tissues are most affected and which normally use LDL receptors to obtain cholesterol. The only cells that we could remove and study were blood cells."

At about the same time as Brown together with Joseph Goldstein and their associates in Texas were trying to understand how a lack of LDL receptors and a consequent surfeit of LDL in the blood can cause heart disease, a veterinarian in Japan made a serendipitous finding that totally changed the prospect for LDL receptor research. In 1973, Yoshio Watanabe of Kobe University noticed that a male rabbit in his colony had ten times the normal concentration of cholesterol in its blood. By appropriate breeding, Watanabe obtained a strain of rabbits, all of which had this very high cholesterol level. These rabbits spontaneously developed coronary artery disease, which is extraordinary because the only way normal rabbits can be made to develop atherosclerosis is to stuff them with dietary cholesterol. The cholesterol-fed rabbits, however, develop cholesterol deposits in all of their blood vessels, not just the coronary arteries. In humans, cholesterol accumulates preferentially in the coronary arteries. Thus the Watanable rabbits develop a heart disease that closely resembles what occurs in humans.

For years, no one made a connection between the Watanabe rabbits and persons with familial hypercholesterolemia. This was because the rabbits have high triglyceride levels as well as high cholesterol, whereas in the human disease only cholesterol is elevated.

Then, in 1980. Watanabe collaborated with biochemists at his university to look for LDL receptors on cultured skin cells from the rabbits. They found that the rabbits, like the humans, lack functional LDL receptors.

Once they realized just what the genetic defect was in Watanabe rabbits, Brown and Goldstein set out to determine which tissues take up LDL. They found that the primary sites are the liver, which excretes cholesterol from the body and also uses cholesterol

to make steroid hormones. Daniel Steinberg and Thomas Carew of the University of California in San Diego made similar observations.

In addition, says Brown, "The second thing we learned- and perhaps the most important - is the nature of the overproduction of LDL in patients with familial hypercholesterolemia. It was observed a long time ago that if you study the turn-over of LDL you can show a deficiency in the removal of LDL from the blood. That is easy to explain on the basis of the lack of receptors. But patients also seemed to produce more LDL than normal individuals. We didn't know how to account for that."

Researchers were faced with a single gene disease that caused both a slow-down in the removal of LDL and an increase in the synthesis of this cholesterol-carrying protein. How, they wondered, could one mutation cause both of these effects? "The study of the Watanabe rabbits allowed us to explain it." says Brown.

It was known that LDL are secreted from the liver in the form of precursor, called very low density lipoproteins (VLDL), which carry triglycerides as well as relatively small amounts of cholesterol. The VLDL go to fatty tissues which remove the triglycerides from them. What remains is a remnant particle that must be removed from the blood.

"What we learned from the Watanabe rabbit is that the removal of the VLDL remnant requires the LDL receptor," Brown remarks. The LDL receptors on the liver cells grab the VLDL remnants and degrade them. "In the Watanabe rabbit. VLDL can't get back into the liver. It remains in the plasma and is eventually converted to LDL. We call this the shunt pathway for LDL production."

In normal persons, by far the majority of the VLDL remnants go to the liver where they bind to LDL receptors and are degraded. A small portion of them escape this degradation and are converted to the cholesterol-carrying protein LDL. This LDL is bound by bodily tissues, especially the adrenal gland, and supplies them with chole - sterol. According to Brown and Goldstein, the shunt pathway is thought to be the sole source of LDL in Plasma. In patients with familial hypercholesterolemia, VLDL remnants remain in the plasma and are converted to LDL thereby accounting for the very high LDL levels in these patients. The LDL receptors thus have a dual effect in controlling LDL levels. They are necessary to prevent over synthesis of LDL from VLDL remnants and they are necessary for the normal removal of LDL from the blood plasma.

Persons who are heterozygotes for familial hypercholesterolemia have one normal gene for LDL receptors, but it is not fully expressed. Based on their new understanding of the control of LDL, David Bilhiemer and Scott Grundy of the University of Texas Health Sciences Center at Dallas, working with Brown and Goldstein, have found a way to trick these heterozygote cells into making a greater number of normal LDL receptors. Moreover, these investigators speculate that their method may also apply to persons who have high cholesterol levels but are not heterozygotes for familial hypercholesterolemia.

Goldstein and Brown had already learned several years ago that LDL receptors in cultured cells are under feed-back regulation - give a cell more LDL and fewer receptors are made. Give it less and more receptors appear. The idea for treating heterozygotes was to deprive the liver of cholesterol. The liver will then make more LDL receptors. A drug, cholestyramine, that is commonly used to lower cholesterol levels, acts in just this way. If essentially drains the liver of cholesterol.

But cholestyramine alone is not sufficient to lower LDL levels to a normal range in heterozygotes for familial hypercholesterolemia. It lowers LDL levels by only 15 to 20 percent so that patients with cholesterol concentrations of 350 milligrams per deciliter reach about 300 milligrams per deciliter - which is still elevated. A more normal cholesterol concentration is 215 milligrams per deciliter.

The reason why cholestyramine is not fully effective, says Brown, is that "the liver makes a dual response. It takes up cholesterol but it also starts to synthesize more cholesterol."What is needed is a second drug to block cholesterol synthesis.

Two new drugs, now in an early experimental stage of testing, seem to fit the bill. Both were isolated from molds and both act by inhibiting an enzyme necessary for cholesterol synthesis. The first of these drugs, called compactin, was discovered by Akira Endo of the Sankyo Drug Company in Tokyo. The second, an even more potent drug called mevinolin, was discovered independently by Endo and by/

When given alone, either compactin or mevinolin will cause a decrease in cholesterol synthesis and a consequent increase in liver LDL receptors. But, says Brown. "The most dramatic effect is when one of these drugs is given with cholestyramine." As first reported by Hiroshi Mabuchi and his associates at Kanazawa University in Japan, the two drug combination causes a 50 to 55 percent decrease in plasma LDL levels in

/ scientists at Merck Sharp & Dohme.

heterozygotes for familial hypercholesterolemia - which puts them in the normal range. Says Brown, "The important scientific point is that here is a genetic disease that is manifested in heterozygotes and we can stimulate the expression of the normal gene. "The immediate clinical importance is that this drug combination may stave off heart disease in the heterozygotes who have. Brown notes, "a grim prognosis now and no alternative treatments."

But the question that is of central interest to the majority of people in this country is: What about persons who have high cholesterol concentrations - say 280 miligrams per deciliter - and a strong family history of heart disease and yet are not affected by familial hypercholesterolemia? They are at high risk of developing heart disease. Should they take these cholesterol-lowering drugs? These questions, of course, extend the findings of the recent research to a much more speculative realm.

It is generally believed that many factors can cause high cholesterol levels in humans. For example, a high cholesterol diet may do it in some people. Dietary cholesterol is carried by a different system than the LDL, which carries endogenous cholesterol made by the body. But Robert Mahley of the University of California in San Francisco, working with Brown and Goldstein, found that when animals are fed cholesterol it accumulates in their livers. The liver's LDL receptors then decrease in number. This causes an increase in the LDL in the blood. It is likely that similar effects occur in humans.

Certain hormones can also affect LDL receptors in humans. For example, Gilbert Thomason and Nicholas Myant of the MRC Laboratory of Lipid Research at Hammersmith Hospital in England found that a lack of thyroid hormone causes high LDL levels in the blood and a decrease in LDL receptors whereas too much thyroid hormone has the opposite effect.

But even though the causes of most cases of high cholesterol levels in humans are only dimly understood. Brown and Goldstein argue that the two-drug method of lowering cholesterol concentrations may be worth trying. "We feel that it will work, "Brown says, And by using these drugs, it may be possible to answer at last the question of whether lowering cholesterol levels lowers the risk of heart disease. For the first time, a treatment is available that lowers cholesterol enough that a difference in heart disease risk, if it occurs, should be readily apparent in a clinical trial.

The most fundamental question about cholesterol and heart disease is still un-answered, however. How does LDL cause heart disease in the first place? But, once again, the Watanabe rabbit may provide the necessary clues. Several groups of researchers have established that the atherosclerosis that develops in these animals is similar to human atherosclerosis. Thus it is possible to use these animals to study how LDL interact with platelets, endothelial cells, scavenger cells, and the smooth muscle cells that line the artery wall. All of these cells seem to be damaged by high levels of LDL. Carew and Stoinberg have recently developed methods to study in whole animals which cells are degrading LDL and how. "We just really have the methodology now in hand - within the last few months," says Carew.

So the unanswered questions in the cholesterol-heart disease story no longer seem so unaswerable as they did in the recent past. The stage is set for dramatic changes in the diagnosis and treatment of heart disease.

(Science, 221, 4616 (September 16, 1983) pp 1664-66)

OUTER SPACE: MANKIND'S FOURTH ENVIRONMENT

BY Lubos Perek

This title was the theme of the Congress of the International Astronautical Federation held in Rome in 1981. The information presented at the Congress, as well as further developments, have demonstrated that outer space, together with the three classic environments of land, sea and air, form a system whose component parts are closely interrelated. All major events - whether they happen on land, in the world's ocean, in the atmosphere or in the near-earth outer space - affect the entire environment, sooner or later. And the healthy state of the environment is a necessary condition for the continued existence of mankind.

Delegations from ninety-four countries convened in Vienna in August 1982 for the conference Unispace' '82, to discuss the state and applications of space science and technology, as well as international co-operation and the role of the United Nations in space activities. They had before them a number of background papers prepared by the United Nations Secretariat, with the assistance of over 200 scientists and experts from many countries. One of these papers dealt with The Relevance of Space Activities to Monitoring of Earth and Resources and Environment and another, with The Impact of space Activities on the Earth and Space Environment. Environmental questions were in the minds of many delegates and appeared in several statements made before the conference. In the report of Unispace'82, a section was also devoted to the nature and protection of the near-earth environment. Thus, the scientific fact that near-earth outer space is part of the environment was accepted by the international community.

Space activities are in their initial stage. Only twenty-five years have elapsed since the launch of the first Sputnik. Since then, in some 2,400 launches, almost 14,000 man-made objects have entered outer space. Of these, almost 9,000 decayed in the atmosphere, impacted on the grou d or were retrieved. Of the remaining 5,000 still in orbit, about 4,000 are non-functional objects or satellites which have terminated their activities. The remaining 1,000-odd objects include all the active satellites engaged in transmitting communications, in remote sensing of the earth and its environment, in meteorological observations, in navigation and geodesy, in verifying disarmament agreements and in scientific research. Not included in these statistics are the unknown thousands of small objects, mostly

debris, which escape detection by tracking radars and telescopes. In relation to the vast expanse of the near-earth outer space, these numbers are small indeed. Yet some of these objects will remain in space for a very long time and continue to move with speeds exceeding that of projectiles. The time is coming when outer space will have to be managed in order to preserve the environment, as well as to maintain the safety of space activities at a reasonable level. This will become un-avoidable in the future (possibly even the not-too-distant future) when an increase in space activities may be expected. Let us compare the present and potential state of space applications.

Present space applications use outer space mainly as a convenient vantage point for observing the earth and other celestial bodies and for transmitting communications. Although these applications are extremely important for the economic, social and cultural life of all nations, future applications will probably cover a much wider range. These may include the preparation of special materials, such as crystals or mixtures of various substances, which are adversely affected by the earth's gravity. The very low gravity on satellites (so-called microgravity) allows crystals to grow in a more uniform way or substances of different densities to mix freely.

One of the most exciting and ambitious projects is the Space Solar Power System. At a time of growing energy needs and scarce energy sources, such a project is most attractive but its size is fantastic. It calls for 60 satellites in the geostationary orbit, each of mass of 50,000 tonnes and a surface of 55 km^2, for collecting solar radiation. The collected energy of five gigawatts per satellite would be converted into microwaves and transmitted to ground antennae, each of which would cover an area of some 170 km^2. It seems that no basic breakthrough in science or technology is needed for constructing such a system. The main problem is the scale of the project and the cost involved, which would require worldwide cooperation. But technical development might bring it closer to reality than it is today. In any case, its possible impact on the environment and possible interference with other activities, such as communications, have to be assessed.

Other projects, for some more distant future, consider the mining of raw materials from the moon or from an asteroid. A space factory for this purpose would save the cost of launching materials from the earth and would spare the earth's environment: only the crews would have to be launched. The millions of

tonnes of material would be mined in space, used in space and moved around by energy collected in space. The number of people involved in such activities would be large and, therefore, permanent (or at least long-term) settlements might have to be established. These projects are, in principle, possible with present-day science and technology, the most difficult problems being scale and finances.

Returning to current problems, another possible space application should be kept in mind although its implementation is by no means certain: things or materials that for some reason cannot be stored on the ground could be disposed of in outer space, in particular in orbits outside the near-earth outer space. The main problems would be finding suitable orbits which would require only reasonable amounts of energy; preventing the undesirable cargo from returning to earth or from affecting any other space activities; and assuring the safety of the entire operation. This might concern the disposal of nuclear wastes for example.

This broad perspective of future space activities will involve a large number of launchings, of satellites, of manned flights. Even if some of the environmental effects are negligible at present, they have to be considered against the background of possible future levels of activity. Wherever a preventive measure might help, it should be adopted now since remedial measures are always much more expensive and difficult, if indeed they are possible at all.

Before discussing the effects of space activities on the environment, let us look at the important contribution of artificial satellites to monitoring the environment. Several satellites have been launched specifically for the purpose of observing the earth's resources and environment. Among them are the satellites of the Landsat (US) series; several flights of the Soyuz-salyut complex (USSR); the meteorological satellites in the geostationary orbit - GMS (Japan). Meteosat (European Space Agency) and GEOS (US): and in the near-polar orbits - Meteor (USSR). Nimbus (US) and Tiros-N(US). The Seasat(US) was geared for ocean observations. And two satellites have also been launched by India (Bhaskara and INSAT) with devices on board to monitor the environment. The instrumentation for environmental studies ranges from direct photographs in various parts of the visible spectrum to multispectral scanning, radar observations and measurements of the surface temperature in the infrared part of the spectrum.

One of the important parameters of a healthy environment is the water content of the soil. This

can be measured from satellites and when images are compared over a period of one or more years, long-term changes can be detected. The colour of the ground is indicative of the vegetation's health, whilst the colour of water shows the amount of silt or aquatic vegetation present. The ocean surface reveals not only the surface temperature, but also ocean currents, eddies and general circulation, salinity, the amount of chlorophyll and the extent of oil spills.

Meteorological satellites monitor the temperature and chemical composition of the atmosphere, in particular the stratosphere. Both parameters are subject to natural variations but it is the long-term changes that might affect conditions on the ground. One important compound is carbon dioxide which is released into the atmosphere through the burning of fossil fuels. Its excessive abundance in the stratosphere would diminish the rate of heat radiated into space and thus raise the temperature on the ground. Vitally important also is the ozone layer. Ozone absorbs solar ultraviolet radiation which is detrimental to life. In fact, the development of life on earth was possible only due to this protective layer of ozone. Chemically, it is very active, reacting with many chemicals which are present in the stratosphere. Among them are man-produced hydrocarbons, oxides of nitrogen and various chlorine compounds.

Satellites also help in predicting and monitoring natural events that adversely affect the environment. Severe storms, such as tropical cyclones or flooding, can be monitored from their inception. Methods of forecasting earthquakes are being improved by measurements of stresses in the earth's crust which show as minute changes of distances between points on a baseline. Satellites make it possible to use baselines hundreds or thousands of kilometres in length. Volcanic eruptions (in particular, the spreading of dust and smoke in the atmosphere) can also be seen from satellites: for example, 24 hours after the eruption of Mount Saint Helens, a spread of dust of more than 200 km was found.

Remote sensing by satellite has become indispensable to the systematic collection of environmental data for various projects of the United Nations Environment Programme (UNEP), including agriculture, land use, climate impact studies and global ozone monitoring.

What comes to mind first when considering the danger of space activities is the possibility of being hit by falling satellite or its debris. The fall of

space objects are not as frequent as one would deduce from the number of objects actually launched. In the first place, satellites at very high orbits are not subject to the drag of the atmosphere and their orbits are governed mainly by the gravitational attraction of the earth, the moon, the sun and other celestial bodies. Non-gravitational forces, such as radiation pressure, only cause slight oscillations of the orbits, not permanent changes. Thus, satellites in the geostationary orbit, as well as in other high orbits, are permanent features for all practical purposes: they will not come down to earth in the next several million years.

Space objects at altitudes over one thousand kilometres have lifetimes over one thousand years. Only on low orbits of a few hundred kilometres are space objects subject to important drag forces. When they come down to altitudes of some 100-160 km. they start to heat by friction with atmospheric gases. This heating becomes quite intense and the objects start evaporating. In many cases, depending on their structure, thickness of the material and other technical properties, space objects completely evaporate in the atmosphere. Only massive and compact parts impact on the ground.

About 500 trackable objects decay each year. The amount of decaying untrackable debris is probably higher but it is likely to evaporate completely in the atmosphere. The rarity of falling space objects is shown by the fact that during twelve years (between 1968 and 1979). Only 14 announcements of impacts were received at the United Nations. Of these, only some two to three cases received wide publicity. At present, the danger posed by artificial space objects is comparable to that posed by natural meteorites. Even the extensive space activities expected in the future need not increase this danger, provided the satellites and launching rockets are designed with a view to minimizing the amount of debris generated during the launch or operation of the satellite. Nor should the planning be restricted to the active lifetime of the satellite; it must include provision for a timely and intentional decay or removal of the satellite from outer space.

Another possible danger concerns the depletion of ozone in the stratosphere. During the ascent of the satellite; gases are released into the high atmosphere that react with the ozone. A rough computation shows that 60 launches of the Space Shuttle per year would deplete the ozone by 0.5 per cent. Although this value is well below losses caused by other natural or anthropogenic causes, monitoring of the ozone layer is highly desirable since the chemistry of the high atmosphere is not yet fully understood. Also, a space project requiring a very high frequency of launchings could change the situation.

Laser radar, used in tracking satellites, may be a further source of danger. The laser beam, which is meant to be reflected from the satelite and return to the observing telescope, might be intercepted by an overflying airplane; the unprotected human eye might be damaged if the laser beam is strong enough. But protective measures are fairly easy. The observer can see whether there are any airplanes in the direction of the laser beam and delay the measurements. Moreover, the laser beam is widened in order to increase the probability of hitting the satellite and, consequently, its intensity is decreased below the dangerous level.

Yet another source of danger (amply discussed during the Apollo flights to the moon) is the possible contamination of the earth's environment with forms of life brought from the moon or other celestial bodies. This would happen only if the life forms on a celestial body had some degree of compatibility with life forms on earth. A very detailed investigation and quarantine of astronauts after the first flight to the moon failed to show that organisms had been brought to earth. In fact, no life at all has been discovered on the moon and there is no proof of life on Mars. When other planets are visited, however, it would be wise to continue taking measures against possible contamination.

A very real and perhaps the most acute danger from space would come from nuclear explosions. A strong explosion would increase atmospheric radioactivity. The contamination would spread out horizontally in the stratosphere and become dangerous wherever a stratospheric mass would break through the troposphere and reach ground level. The effects of such an explosion would be quite extensive in the high atmosphere. It would destroy electronic devices on satellites, create an artificial aurora and increase the population of electrically charged particles in the radiation belts or even create an artificial radiation belt. Some of these effects could last several years. Fortunately, nuclear explosions have been prohibited by the Partial Test Ban Treaty of 1963, which banned nuclear explosions in the atmosphere, in outer space and under water. Thus, the best course of action is to ensure that the Partial Test Ban Treaty continues to be observed. It has been ratified by about two-thirds of the world's States. Even if many of the remaining States do not possess the technical capability of launching satellites with nuclear bombs, everybody would feel safer if the Treaty was adhered to by all States.

Let us not forget the possible effects of energy transmission from space solar power stations through the atmosphere to ground antennae. This will be carried out at the microwave frequency of 2.45 GHz which is currently used for industrial purposes. The great width of the energetic beams would make their density fairly low and a short exposure to the radiation would probably be harmless. Little is known, however, about the biological effects of long exposures to low-level microwave radiation. Workers on the ground antennae, as well as in space, would be exposed to higher levels of radiation, There are also other risks connected with the solar power stations but they will depend on the technology used at that time.

Pollution at ground level occurs at the launch site . A large cloud of exhaust gases, cooling water, sand and dust is expelled but it settles and disperses soon after. Since launch sites are far removed from populated areas for safety reasons, the pollution has only local effects. More important is the pollution of the atmosphere by exotic elements and compounds. Of particular concern may be beryllium and cadmium, as well as nitrogen oxides and soot particles which attack ozone. The sensitivity of the atmosphere to pollution increases with altitude; here the density is low and any amount of foreign gases becomes relatively more important. Therefore, even minor sources of gases(such as outgassing, leakage, dumping of water or exhausts from auxiliary power units) may have to be taken into account, depending on the elements and amounts concerned.

Experiments have been conducted on the release of various gases from satellites for scientific purposes. Light metal vapours, which are visible when illuminated by the sun, are used to determine the speed and direction of winds in the upper atmosphere. In this way, it is also possible to study chemical reactions and electrical fields at altitudes inaccessible to other scientific methods. Released gases, although diluted, may remain in the atmosphere for months and affect the natural environment. Further experiments should be undertaken with a better understanding of the lifetimes of the released gas clouds and of the chemistry and mechanisms which will finally restore normal conditions.

The ionosphere, which is important for radio communications over large distances, is sensitive to all agents which affect electrically charged particles. Even water vapour affects the ionosphere because it removes free electrons. Gases injected into the ionosphere spread horizontally over large distances and

remain there for long periods of time, causing deviations from the normal radio propagation. Holes may literally be blown in the ionosphere. Measurements conducted during the launch of Skylab have shown that an area with a diameter of 2,000 km was affected for several hours.

On the other hand, the atmosphere has powerful and sturdy mechanisms for restoring normal conditions. It has a kind of healing capacity and can handle natural effects such as streams of highly energetic particles and radiation from the sun or the influx of some 10,000 kg of meteoritic mass per day. Most of this meteoritic mass, including metals, evaporates. In considering man-made pollution of the atmosphere, it is rather a question of not overstepping certain limits, of not overloading the natural healing capacity of the atmosphere to the point of no return.

Adequate protection of scientific research is important from several points of view. Without research even into such remote realms as astronomy, there would be no future for manking - and we may not even have attained the present. The understanding of the environment and devising methods for its protection depend heavily on such research.

Optical astronomy may be affected by space activities due to traces of artificial space objects appearing on astronomical photographs, leading to the possible misinterpretation of short-term phenomena. Other phenomena can be repeatedly observed and spurious effects eliminated. Astronomy in the infrared part of the spectrum is affected by space objects which have a room temperature (and most active satellites have) and emit infrared radiation. The hot exhaust gases of rockets also do this. Radio-astronomy uses very large telescopes capable of registering extremely faint radio signals. Stray radiation or side-lobes of emission antennae are most harmful. For this reason, the International Telecommunication Union recognized radioastronomy as a 'service' and allocated to it certain frequency bands which are most important for studying distant parts of the universe.

One space mission could pollute the near-earth outer space in such a way that other missions would be harmfully affected. The worst possible scenario is, of course, warfare in space. In wartime, or even under confrontation, it could hardly be expected that any restriction of pollution or removal of polluting agents would be carried out or that measures would be implemented for accommodating other space missions.

Even peaceful activities may adversely affect other space missions. The most obvious is a direct collision. Such an event used to be summarily dismissed by pointing out that the great distances which, on average, separate space objects are sufficient to make such a collision unlikely. However, threeparameters determine collision probability: besides the number of objects in a unit of space, the size of the satellites and their relative velocities must be considered. Of particular relevance is the speed, which in most cases exceeds that of a projectile. Any collision in space, even with a very small piece of debris, will be damaging or lethal. Computations have shown that a collision at a speed of 10 km/sec would eject from a satellite more than one hundred times the mass of the impacting debris. Sudden malfunctions of satellites may have been caused by collisions, although it is almost impossible to prove. The failures of GEOS 2 and Cosmos 954 have, in fact, been attributed to possible collisions with space debris.

The amount of debris in space depends on the level of space activities. Improved technology may considerably restrict the debris put into orbit, either at the launch or during the operation or manoeuvres of a satellite. Another important factor is the atmosphere which limits the lifetime of debris in low orbits. The density of the atmosphere is subject to significant variations connected with solar activity. When the density is high, space debris decays sooner and at higher altitudes than normally. This is another instance of the healing capacity of the atmosphere. The low orbits are cleaned of debris at the maximum of solar activity which occurs every eleven years. The slight decrease in the number of trackable space objects in 1979 and 1980 is probably caused by improved technology, as well as the recent solar maximum, since the number of launches per year remained more or less constant in the last fifteen years.

At present, the probability of a collision between two space objects does not exceed one collision in ten years. But again, preventive measures are so much cheaper and easier than remedies; it is absolutely unnecessary to pollute the near-earth outer space as we have already done to 'inner space' - the world's oceans.

There are other possible adverse effects, such as interference by electromagnetic fields, radiation or shadowing during close encounters of space objects, all of which will have to be tackled fairly soon. Due credit must be given in this context to the work of the International Telecommunication Union which co-ordinates the frequency spectrum and orbital positions

in the geostationary orbit in such a way that harmful interference to communications are prevented. Let us hope that the more general question of all possible interference will be handled with similar success.

Because of the global character of space activities, all meaningful arrangements have be instituted on an international level. Thus, many of the steps for protecting the near-earth outer space as part of the environment and for maintaining or increasing safety of space activities can be carried out only by launching agencies. There is, however, some role for the individual. Everybody should understand about outer space. It is not immensely distant: it is only a few minutes away by rocket flight and it is all around us. And what happens in space will have repercussions in the atmosphere and on the ground.

The primary aim must be to preserve outer space as an area of peaceful activities. This was clearly stated at the conference Unispace '82 held in Vienna last year:

> The extension of an arms race into outer space is a matter of grave concern to the international community. It is detrimental to humanity as a whole and therefore should be prevented. All nations, in particular those with major space capabilities, are urged to contribute actively to the goal of preventing an arms race in outer space and to refrain from any action contrary to that aim.

The second aim must be to work towards international agreement on a code of conduct in outer space for the protection of the near-earth outer space, as well as for keeping outer space safe for all peaceful uses. In concrete terms, the possible impact of space activities on the environment should continue to be studied and preventive measures taken wherever necessary. Of particular importance is the monitoring of the possible depletion of the ozone layer, the abundance of carbon dioxide, and the presence of anthropogenic chemical compounds in the high atmosphere. The amount of space debris should be reduced as far as feasible and inactive satellites removed from orbits used for active space missions.

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ACID RAIN ON ACID SOIL: A NEW PERSPECTIVE

by Edward C. Krug and Charles R. Frink

Acid rain is widely considered one of our most serious environmental problems. In landscapes where hydrology and geochemistry do not allow complete neutralization of acid runoff, acid rain is thought to be acidifying lakes and streams, as well as mobilizing aluminum and other metals toxic to fish and plants. Nutrients are also thought to be depleted by acid rain, raising concern about large areas of productive forests located on soils that are strongly acid and low in nutrients. A gradual acidification and sterilization of our soild and water, particularly in parts of the Adirondacks, northern New England, southeastern Canada, and southern Scandinavia, is predicted.

From its inception, however, soil formation in humid temperature climates is an acidifying process, mediated by the classic factors of geology, climate, biology, topography, and time. Indeed, the factors thought to make landscapes sensitive to acid rain are those that develop some of the most acid soils in the world. The results of natural soil formation are those attributed to acid rain: leaching of nutrients, release of aluminum, and acidification of soil and water.

Landscapes have usually been assumed to act merely as net sinks for acid rain but generation of acidity in soils has recently been recognized as an additional source. This is evident in reports of the Norwegian project on "Acid Precipitation - Effects on Forests and Fish" (the SNSF project), for example However, acid rain is still considered principally responsible for regional acidification , because the increased flux of SO_4^{2-} in rain is thought to result in equivalent leaching of hydrogen ions and other cations. We believe that this assessment needs reexamination. Large amounts of humic acids are present in forested landscapes thought to be particularly sensitive to acid rain. The solubility of these humic acids is controlled by p^H, and hence they effectively regulate both acidity and anion flux.

In this article we define acidity in relation to rain and soil, describe how soil formation can acidify soil and water as well as leach nutrients and aluminum, show how humic acids buffer soils, and finally discuss the impact of changing land use and consequent vegetational succession. We wish to show that natural soil formation is often more important than acid rain in determining the acidity of lakes and streams.

Acidity of Rain and Soil

Rain in equilibrium with carbon dioxide in the air has a pH of about 5.6. Rain at pH 4.6 is often said to be ten times more acidic, but this neglects the acidity of undissociated carbonic acid (H_2CO_3) normally present in rain. The strong acid necessary to reduce the pH of rain from 5.6 to 4.6 actually represents a twofold rather than a tenfold increase in total acidity.

The acidity of rain has also been expressed in terms of the amount of limestone, $CaCO_3$ that can be neutralized or leached from the soil, $CaCO_3$, but the amounts that can be dissolved by rain at pH 5.6 are often ignored. An annual rainfall of 1 meter per hectare at pH 5.6 can dissolve 400 to 500 kilograms of $CaCO_3$ per hectare, depending on the values of the thermodynamic constants used. Rain at pH 4.6 can dissolve an additional 10 to 12 kg/ha, and rain strongly acidified to pH 4 can dissolve an additional 50 kg/ha or about 1 kiloequivalent per hectare. For comparison, managed agricultural soils in the northeastern United States may require limestone additions of 50 to 100 kg/ha per annum.

Measurements of acid in soil are some-what analogous to measurements of acid in rain. With clay minerals and organic macromolecules acting as immobile anion phases, soils resemble weak acids, making a thermodynamic interpretation of soil pH uncertain. However, certain principles apply: increasing concentrations of neutral salt decrease the measured pH, whereas increasing dilution with water increases pH. This salt effect is significant in measuring acidification of runoff.

The exchange acidity of soil is the analog of the total acidity of rain and is defined in terms of hydrogen ions readily exchanged by neutral salts. Acid humus typically has an exchange acidity of about 1 eq/kg, which is about 10,000 times greater than its acidity expressed as pH. In mineral soils, much exchange acidity is produced by hydrolysis of ionic aluminum. Hence, at pH values that are typical of strongly acid soils, ion exchange sites on minerals are occupied primarily by ionic aluminum and some additional aluminum is complexed by organic matter, giving a total exchange acidity on the order of 1000 keq/ha.

Soil Formation

The more mature a soil is the more it differs from its parent material, although the degree of difference is strongly influenced by geology. In humid temperate

climates soils are more acid than their parent materials; water percolating through freshly ground granite is alkaline (pH 8 to 9), but soils developed from granite are acid. There is sufficient acidification that mature soils developed even on limestone or marble can be acid. Although chemical oxidation of reduced elements in parent materials produces acidity, it cannot account for the extremely acid podzols and related peats found on granite-like rocks. Acidification of these soils is biological ; hence, the soils are most acid at the surface, where most decomposition and leaching occurs.

The major sources and sinks of soil acidity are illustrated in Fig. Initially, weathering of freshly exposed siliceous bedrock is rapid and bases such as calcium, magnesium, potassium, and sodium are leached. (. Acid is generated by the biological oxidation of carbon, nitrogen, and sulfur, much as acid rain is created by the burning of fossil fuels. Because the partial pressure of CO_2 in soils can be 100 times that in the air, potential weathering rates by H_2CO_3 are immense, although seldom achieved in nature.[2] Reaction and removal of hydrogen ions favor continued dissociation to H^+ and HCO_3^- (pathway 2c). With time, rates of acid neutralization, weathering, and cation denudation decrease and acids accumulate. Little H_2CO_3 is consumed by mineral weathering, most of it is lost as CO_2 and H_2O. This is reflected by the low bicarbonate alkalinity of runoff from watersheds with strongly acid soils.

A layer of humus eventually forms which often lies over bleached mineral soil. Earthworms and other organisms that mix litter with mineral soil are now absent, and microbial populations have changed. Production of simple organic acids is slight, but production of partially oxidized humic acids of high molecular weight is favored . These humic acids more strongly acidify their environment than the final oxidation products of CO_2 and H_2O. The increased acidity decreases the solubility of humic acids , and enhances their accumulation. The rate of mineral weathering is now exceedingly low, most organic acids are lost as CO_2 and H_2O, and the upper mineral soil is a highly weathered siliceous residue. This process is known as podzolization, and soils with distinctive bleached horizons are known as podzols.

resistant to acid weathering.

It is often thought that acid humus accumulates because organic matter decomposes slowly. This is clearly true where thick peat develops under sparse vegetation. It is not true for the productive forests on podzolized acid soils in the Northeast, southeastern Canada, and Scandinavia, where concern about acid rain is greatest.

Formation of mature podzol soils from freshly exposed materials is measured in thousands of years, because the capacity of the parent material to neutralize acid is great relative to rates of weathering. For example, the potential for neutralization of acids by the parent material at Hubbard Brook in New Hampshire is nearly 21,000 times greater than the yearly inputs of acid rain and 11,000 times greater than the estimated rate of mineral weathering.

In addition, the aluminum oxides in the parent material neutralize acid in water when the pH is below 5 and serve as an enormous sink against acidification.

Although some preferential flow occurs in soils, so that not all ion exchange sites can react equally with leachate, the time scale of weathering allows distinctive soil horizons to develop parallel to the earth's surface rather than surrounding vertical channels of preferential flow. Given the rate of soil formation, or even the 100 or more years said to be necessary for significant leaching of cations by acid rain, strong acidification of mineral soil profile. In addition, the earth's surface is not stable: erosion, tree throw, frost heaving, and soil creep constantly expose new and less weathered mineral material. Althogh the amounts of soil moved are small, the corresponding resistance to acidification is large. Only where weathering can keep pace with disturbance do we see mature, albeit heterogeneous, soil development.

Acidification of Soil and Water

Because cation exchange reactions are rapid, hydrogen ions in acid rain could rapidly acidify soil by depleting exchangeable base nutrients. If increases in H^+ in acid rain (ΔM) leached nutrient cations (ΔM) from soils on a charge-equivalent basis (that is, $\Delta M/\Delta H = 1$), strongly acid soils would be highly susceptible to acidification because of their low nutrient content. However, the ability of hydrogen ions to remove nutrient cations from soils more acid than pH5 is low; that is, $\Delta M/\Delta H \leq 1$ at the mean pH of present-day acid rain. Conversely, base nutrient cations are efficiently retained. Data on acid soils and acid rain in areas of concern around the world show that, on average, the proportion of bases to acid in the rain is usually equal to or greater than that in the strongly acid forest soils on which the rain falls.

Artificial leaching experiments, some of which have lasted up to 5 years, verify that acid rain at pH 4 or higher is inefficient in replacing base cations

/ is generally restricted to the upper soil

from podzols and related acid soils . As soil pH increases above 5, base cations are replaced more efficiently. Thus, the less acid soils with low cation exchange capacity developed on coarse siliceous materials are actually more susceptible to acidification. Little research has been conducted on the impact of acid rain on such soils.

Bicarbonate alkalinity is the principal measure of the ability of lakes to resist acidification. In highly siliceous water-sheds with acid soils where rates of mineral weathering by H_2CO_3 are low, inputs of HCO_3^- per unit drainage area are also low. Lakes in such watersheds with small ratios of drainage area to lake area could be acidified by acid rain falling directly on them. Little change in pH will occur until 80 to 90 percent of the bicarbonate has been neutralized. One lake in Canada that occupies about 40 percent of an entire watershed has apparently been directly acidified by acid ran. However, this direct acidification is usually considered a minor factor relative to acid runoff .

Alpine-like lakes and streams in granitic terrain are believed to be especially vulnerable, particularly where there is little mineral soil and permeable geologic material to neutralize runoff from acid rain. Also, the relatively steep and short slopes of these landscapes minimize infiltration and time of contact with neutralizing minerals. The granitic shield and similar areas of eastern North America and northern Europe also have large proportions of extremely acid peats with only small amounts of weatherable minerals. Because these peats often border lakes and streams, they can exert a disproportionately large influence on water chemistry. For example, acid peats cover 24 percent of a watershed in southernmost Norway, and 62 percent of the drainage flows through them.

The factors thought to make these landscapes sensitive to acid rain also limit neutralization of runoff acidified by acid soil. The thin and rocky soils that develop on these areas naturally produce such thick humus that they are often classified as organic soils, and they have a lower pH than the thicker soils downslope. This topographic gradient in soil chemistry and other properties, where the upland soils are"leaky" and act as A horizons and the lower-lying sites act as B horizons, is known as a geochemical soil catena. Thus, a gradient in stream acidity paralleling a soil catena in mountainous areas should not be surprising, although it is not always evident. Such gradients have been observed at Hubbard Brook and other mountainous

watersheds in the northeastern United States, but the acidification has been attributed entirely to acid rain.

The interim report of the SNSF project attributed acid runoff solely to acid rain. This evoked criticism from other Scandinavian scientists, who noted that the amount of acid in soils are enormous relative to that in rain and that runoff from acid soils will be acid regardless of the pH of rain. They suggested that in such watersheds, runoff from heavy rains and rapid snowmelts is acidified because a greater proportion is in contact with the most acid surface soil horizons. Thus, hydrologic factors can make rapid runoff significantly more acid than runoff from gentler rains or slower snowmelts, which percolate to a greater depth and more slowly through less acid subsoil and geologic materials. In short, the effects of acid rain were said to be confused with those of acid soil.

A later report of the SNSF project acknowledged that soils can act as both sources and sinks for acid and that the effects of acid rain were not clearly expressed even in watersheds as small as 10 ha. Accordingly, "Minicatchments" ranging in size from 0.003 to 0.026 ha were established. Because of their small size, shallow soil, and large areas of exposed bedrock (46 to 74 percent), these catchments represent a worst case where the effects of acid rain should be most evident.

On average, runoff in the minicatchments was twice as acid as the acid rain, and the pH of the runoff was correlated with soil pH. Only for the heaviest rains in the smaller basins was the pH of rain found to measurably affect the pH of runoff. There was essentially no difference in acidity between the snowmelt from a snowpack at pH4.3 and that from a snowpack neutralized to about pH 7. Artificial rain at pH 3.85 acidified runoff by 0.2 to 0.4 pH unit, but it was concluded that further studies were needed to determine whether such acid rain can measurably acidify runoff in larger watersheds.

Although it has been demonstrated that acid soils can acidify runoff, it is still contended that acid rain is the major factor in the acidification of leachate and runoff. We believe that this is due to a number of misconceptions. One of them concerns anion leaching As we noted earlier, hydrogenions in acid rain at pH 4 or greater are inefficient in exchanging bases and thereby in acidifying strongly acid soils. Accordingly most of the hydrogen ions in rain are thought to remain in solutionand move through the soil accompanied by sulfate as the principal anion. Sulfur in rain

generally exceeds the nutrient requirements of forests, and humic materials coat aluminum and iron oxides that might otherwise immobilize sulfate by anion fixation. Thus, most of the H_2SO_4 falling on these soils is thought to move through them, causing increased cation leaching proportional to the increased flux of SO_4^{2-}. Similarly, acid peats are considered to offer little resistance to acidification of runoff by acid rain.

However, the anion leaching theory has a major flaw. Watersheds considered to be most sensitive to acid and rich in humus, and their chemistry is not one of simple ion exchange. Humic materials act as weak acids; they dissolve in water and color and acidify it. The solubility of humic materials is a function of pH: the more acid the water, the less is dissolved. Sulfate apparently does not react strongly with humic materials, but the added H^+ in acid rain hinders their dissociation and decreases their solubility. The response is analogous to that of an inorganic system containing an excess of a sparingly soluble solid phase. Thus, additions of H_2SO_4 in rain should increase the flux of SO_4^{2-} and decrease the flux of organic anions with little or no measurable change in pH. Organic acid that accumulate are fated to be oxidized to CO_2 and H_2O.

Such a buffering mechanism helps explain why acid rain does not increase cation leaching in strongly acid soils at rates equivalent to deposition. Rates of cation export from watersheds in the northeastern United States, Canada, and Norway which are thought to be sensitive to acid rain are remarkably low. Investigators at Hubbard Brook found it perplexing that the rate of cation export from the watershed was unusually low and apparently not enhanced by acid rain. Johnson reported that "geologically, no excessive chemical weathering activity (as measured by cation export from watersheds) can be attributed to acid rain over the northeastern United States."

Other researchers state that the strong acids in acid rain result in equivalent leaching of cations, but this conclusion is not supported by their own data. For example, rates of loss of cations in rivers in Canada are lowest where inputs of acid rain are highest. If the assumption of equivalent leaching were strictly applied to Norwegian data there should be no net loss of cations without acid rain, because net losses of cations are equivalent to inputs of acid in acid rain.

The organic acid buffering mechanism also offers an alternative explanation of the observation that humic-colored lakes in Scandinavia are becoming clearer, an effect previously attributed to precipitation of humic acid by iron and aluminum dissolved by acid rain.

Leaching of Aluminum

The presence of aluminum ions in solution in soil and water at pH 5 or less has been considered evidence of dissolution of aluminum by acid rain. Even though it has long been known that large amounts of soluble aluminum are present in acid soils, the discovery of leaching of soil aluminum by acid rain has been described as a principal and historic contribution. The discovery was based on the observation that there is considerably less aluminum mobilization in "pristine" sites in New Mexico and Washington than in "Polluted" sites at Mount Moosilauke in New Hampshire. This is not surprising, however, since the soils in New Mexico and Washington are naturally less acid than those in New Hampshire.

There is a further misconception that aluminum leached from the A horizon of podzols is normally immobilized in the B horizon must have been dissolved by acid rain. Such movement of aluminum out of soils is implicit in the concept of the geochemical soil catena. Some aluminum is leached and may appear in surface waters, as shown in 1930 by Joffe and later by others. Indeed, at the sites in Washington examined by Ugolini and co-workers one-third to one-half of the aluminum from the A horizon remains in solution in the B horizon. Aluminum does not appear in nearby spring water because it is precipitated as the water moves through fractured basic andesite bedrock. In New Hampshire, on the other hand, the water moves rapidly over solid bedrock, and hence aluminum appears in adjacent spring water.

The belief that aluminum ions in water result from acid rain is supported by the idea that all aluminum leached from organic-rich soils is complexed by organic anions. In humic-rich soils at pH4.5 to 5, humic materials do complex most of the aluminum, as shown 50 years ago. However, aluminum complexation decreases dramatically as the pH decreases below about 4.5. Likewise, the solubility and mobility of complexed aluminum decrease as acidity increases. Accordingly, ionized aluminum should be expected in water draining from organic-rich soils at pH4 or less. This may also help explain why more aluminum is leached from the upper soild horizons at the Washington sites at pH 4.5 to 4.7 than at the New Hampshire site at pH 4.

Basic cations in rain may also promote exchange of ionized aluminum from acid soil into leachate and runoff. Indeed, the data from the snowmelt study mentioned earlier suggest that sodium in the neutralized snowpack replaced aluminum on exchange sites,

which increased the concentration of aluminum in runoff for several weeks to about twice that in corresponding runoff from the snowpack with pH 4.3. Acid rain may also increase the concentrations of base cations in forest throughfall. For example, about 90 percent of the hydrogen ions in acid rain at Hubbard Brook are neutralized in the northern hardwood canopy during the growing season; pH 4.1 rain becomes pH 5.0 throughfall. Although these leached nutrient cations are apparently taken up by the forest, the effects on aluminum chemistry are not known. Future studies should be carefully designed so that ion exchange by neutral salts (the salt effect) is not confused with dissolution of aluminum by acid.

Effects of Changing Land Use

Both regional acid rain and drastic changes in land use are associated with societal and technological evolution. Earlier, the exploitation of temperate forests was widespread and highly destructive. The remaining forests of western Europe all show the influence of man. The extensive heaths of Great Britain, Scandinavia, and northern Europe are the consequences of earlier and careless land use. Several thousand years of burning, grazing, and cutting caused severe erosion, which helped to create the unusually thin soils and low treelines of the uplands and low mountains of southern Norway. Many of these practices were transported to eastern North America with the arrival of the Europeans more than three centuries ago.

Fortunately, the temperate forests in Europe and North America were sufficiently resilient that they are now recovering. In New England, the volume of standing wood has increased by about 70 percent between 1952 and 1976. Worldwide, temperate forest regrowth is so great that it may influence the global carbon cycle. Given the effects of vegetation on soil acidification, there is little doubt that recovery of landscapes from earlier disturbance can result in increasingly acid surface soil horizons and thickening and acidification of forest floors.

In the 1920's, Salisbury demonstrated that successional change and forest recovery from previous exploitation were responsible for widespread acidification of British landscapes; the upper slopes, with their acidophilic vegetation, were shown to be undergoing the greatest acidification. Large-scale recovery of forests in New England stimulated early studies in Connecticut. Red pine planted in 1900 on abandoned corn and

tobacco fields developed a forest floor with a pH of about 3.8. Other plots were established in 1926 and 1927 in 20 to 40 year-old hardwood stands and have been protected from cutting and burning. Our measurements show that today hardwoods have acidified the forest floor at one site from about pH 5.5 to 3.9 and the underlying mineral soil from pH 5.1 to 4.6. At another site there was almost complete mortality of oak from drought and defoliation. Basal area declined from 30.5 m^2/ha in 1957 to 4.6 m^2/ha in 1977. Here, we found that the pH of the forest floor had actually increased from 3.8 to 4.2.

While soil properties and effects of changing land use vary from site to site and are even heterogeneous within sites, some general relations are evident, Land use and forest management studies in North America and northern Europe reveal that disturbance under conifers affects acidity and depth of humus more than similar disturbance under hardwoods. Likewise, the greater the disturbance, the greater the effect. Mixed hardwood-conifer forestsare intermediate, but their response to disturbance tends to resemble that of conifers. Thus, as Salisbury concluded., recovery from earlier disturbance will have its greatest effects on the upper slopes - that is, on strongly acid soils rich in organic matter.

In the northeastern United States, the most sever changes have occurred in the spruce-fir forests of northern New England and on the steep slopes of the Adirondacks, where acid rain is thought to be particularly harmful. By the early 1900's essentially all the spruce-fir forests had been clear cut for pulp, except for a small fraction of the forest in the Adirondacks which was preserved. The original spruce-fir forests were very resistant to fire, but lumbering was often followed by severe fires that largely or comple - tely destroyed the thick forest floor.

The more intense a forest fire, the greater the effects on depth and acidity of the forest floor. Organic acids are oxidized and lost to the atmosphere, leaving alkaline ash on the soil. In managed spruce forests in Scandinavia, where controlled burning reduced the depth of humus by only 1 cm, the pH of the remaining 4 cm of humus rose 2 to 3 units. After 50 years the original depth of humus was restored, as was the original pH of 4. The pH of the upper mineral soil was still elevated by about 0.2 pH unit.

The depth of the forest floor under undisturbed stands of spruce and fir on the upper slopes of the Adirondack, White, and Laurentian mountains commonly exceeds 30 cm and the pH is less than 3.5. Diebold showed that in the Adirondacks, fir in spruce-fir slope forests is more destructive to the forest floor than in other forest types. On the average, the depth of the forest floor up to 30 years after burning was reduced by 30 cm. The thinner and less acid forest floors of the lower slopes and valleys were reduced by 5 to 13 cm.

On the steeper slopes of the White Mountains the depth of the forest floor ranges from discontinuous to 5 to 10 cm, suggesting widespread destruction of the original forest floor. The depth of the forest floor may also be reduced in the absence of fire; in cutover but unburned Adironback spruce forests the floor averages about 5 cm in depth.

The effect of cutting and burning on the pH of the forest floor on the steep slopes of the Adirondacks has apparently not been determined. In the various forest types of the lower slopes and valleys, Young showed reductions in the depth of the forest floor from both cutting and burning that were similar to those reported by Diebold. The pH of the forest floor averaged about 4 in undisturbed stands, but under stands that were cut or burned the average pH was about 5 when measured 20 to 50 years after disturbance. The pH of the mineral soil averaged about 0.7 unit higher under disturbed stands.

Maturation of forests also influences hydrology. As the depth of humus increases, the amount of water percolating into the subsoil may decrease. Runoff can become more acid not only because of the increasingly acid humus, but also because of the increasing proportion of near-surface runoff. Also, snowpacks last longer under older forests, making episodic flushes more likely during periods of warm weather or rainfall. The devastating effects of spring snowmelt may be more severe in part because of changes in hydrology and chemistry induced by changes in the forest.

Although the effects of forest disturbance and recovery are variable, it is apparent that recovery results in increasingly acid soil horizons and thickening organic horizons. Accordingly, water moving through such soil should also become more acid, and the proportion of ionized aluminum to organically complexed aluminum may also increase.

Thus, mountainous areas of the northeastern United States are not pristine environments that are acted on only by acid rain. These landscapes, which were disturbed in the past, are undergoing the soil formation process that produce the greatest increases in natural soil acidity.

The idea that changing land use and consequent vegetational succession are largely responsible for acidification of soil and water in southern Norway was first advanced by Rosenqvist. Forest recovery in southernmost Norway has been dramatic:the volume of standing wood increased by more than 70 percent during the period 1927-1928 to 1964-1973. Rosenqvist proposed that this large-scale recovery of forest and the reversion of land to acid heath and forest was producing large areas of increasingly acid soils. As an illustration, he showed that the exchange acidity of surface humus under a 90 year old spruce forest on an abandoned Norwegian farm was equivalent to the strong acids in about 1000 years of rain of 1 m per year with pH 4.3. He proposed that these increasing amounts of increasingly acid humus and mineral soil are acidifying runoff in watersheds where there is incomplete neutralization of acids by mineral weathering.

The final report of the SNSF project acknowledges that changes in land use and consequent vegetative succession have long been known to acidify soil and will in general affect the alkalinity and pH of rivers and lakes. Nevertheless, it considers changes in land use to be a minor factor and concludes that the observed increases in sulfate in runoff and presumed equivalent increases in leaching of hydrogen, aluminum, and other cations are responsible for most of the observed increases in acidity.

We believe that the effects of changing land use and vegetative succession cannot be dismissed on the basis of studies performed to date. Further, the hypothesis that increased deposition of acid and sulfate is causing equivalent leaching and acidification is theoretically unsound and is not supported by direct observations. Natural processes of acidification must be more carefully considered in assessing benefits expected from proposed reductions in emissions of oxides of sulfur and nitrogen.

Science, 221, 4610 (August 5, 1983) pp. 520-25)

EMISSION CONTROL WILL CONTROL ACID RAIN

An expert panel finds that emission reductions will produce proportionate reductions in acid deposition, but it says there is a catch.

by Rechard A. Kerr

A panel of the National Research Council (NRC) has concluded that, contrary to industry claims, a 50 percent reduction in the emissions of sulfur and nitrogen gases will produce about a 50 percent reduction in the acids falling on the land and water downwind of the emission source. That clears a major roadblock to the formulation of a control policy - every dollar invested in emission control should generate the maximum return in the reduction of acid deposition and the damage it causes.

The catch, says the panel, is that scientists cannot be specific about exactly where the reduction in deposition will occur. The computer models that simulate the atmospheric transport and deposition of acid are too inaccurate to say where in eastern North America emissions will end up, the panel found. The modelers doing the research, who were not represented on the eight-man panel, tend to disagree.

The panel based its conclusion - that there is a nearly proportionate or linear relation between emission and deposition - on both historical and laboratory data. The panel cast doubt on any computer simulations of the transformation of sulfur dioxide gas into sulfuric acid that do not regenerate intermediate chemical species essential to the continued oxidation of the sulfur dioxide. Some combinations of chemical reactions seemed to oxidize sulfur dioxide while consuming reactive hydroxyl radicals in the atmosphere, which would allow additional sulfur dioxide to accumulate. Reductions in emission would thus tend to reduce the accumulation of sulfur dioxide but not the production of acid. A similar nonlinear relationship complicates the control of ozone production in urban smog. But the panel suggested that the reasonable replacement of one of the 19 chemical reactions with one that allows the regeneration of reactive intermediates would make the transformation linear. Recent laboratory experiments support the existence of such linear reactions in the atmosphere, the panel said.

Historical records of acid deposition at the Hubbard Brook Experimental Forest in New Hampshire, the only North American site offering a reliable,

longterm record, also suggest that acid deposition responds in full measure to changes in emission. More extensive records in Europe have indicated that increasing emissions there have not led to proportionate increases in deposition. But the panel noted that the deposition of sulfate at Hubbard Brook has decreased about 33 percent since 1965 while sulfur emissions in the eastern United States decreased 8 percent and emissions in the Northeast decreased about 40 percent. "The nitrate deposition data also appear to reflect emission trends in the Northeast," noted the panel report. The panel also cited the relative uniformity of the proportions of sulfate and nitrate deposited across the eastern United States as evidence of the linearity of the chemical reactions involved. The oxidation reactions of some proposed nonlinear schemes predict a preference for the production of nitric acid over sulfuric acid near the source and a shift toward more efficient production of sulfuric acid with increasing distance downwind.

Nonlinear transformation into acids probably exists, the panel concluded, but it does not appear to be of significance over broad areas of eastern North America. Europe's differing meteorology, distribution of sources, or location of receptor areas may bring nonlinear reactions into play there. They may also be significant near American sources, notes Perry Sampson of the University of Michigan, but over large distances between a major source area, such as the Adirondacks, nonlinear chemical reactions would appear to be insignificant.

Emission reduction will help, but the panel could not say where it would be most effective. At a press conference, Jack Calvert, a chemist at the National Center for Atmospheric Research and chairman of the committee, explained why the panel could not be more specific, "Based on our analyses of both the available data and currently available computer models of long-range transport, we conclude that the relative importance of long-range and nearby sources to the acidification of sensitive areas cannot be determined with reasonable certainty at this time." The current models are "very approximate" and "are not formulated from first principles of physics and chemistry." In addition, field observations are too limited to validate models sufficiently.

Modelers of long-range transport tend to think that their present, admittedly simple, models are not all that bad. The differing perceptions seem to go back to a comparison of the performance of nine models during the technical work for the memorandum of understanding (MOI) between Canada and the United States. Both the NRC committee and the White House-appointed

MOI review panel , which also holds modeling in low esteem, appear to have leaned heavily on the MOI analysis. Neither group includes any modelers, but those modelers contacted by Science believe that the MOI analysis had severe limitations. They include the limited 1978 data used for validation, the unusual meteorological conditions during parts of 1978, and the comparison of models of varying sophistication and differing intended uses.

Despite these problems, notes Sampson, the relative importance of various source regions was similar from model to model. James Young, the Canadian technical coordinator for the MOI model comparison, says that model validation with the more extensive and reliable data from 1980 has been considerably more successful than included in the earlier MOI work. All in all, many modelers believe that if the proper model is run enough times, they can now determine with some confidence the relative importance of a major source region in the transport of acid into a distant region. How much confidence will be enough in the political process of policy-making remains to be seen.

(Science, 221, 4607 (July 15, 1983) p.254)

CHINA FACES ENVIRONMENTAL CHALLENGE

A new book and recent Chinese publications cite massive deforestation, expanding deserts and heavy pollution of land, water, and air

by Marjorie Sun

In recent years, China has begun to face enormous environmental problems. In agriculture and industry alike, government policies have led to massive pollution of land, air, and water, and the destruction of much of its natural resources. According to one scientist, the situation has deteriorated to the point that the government is undermining its own goals to modernize and expand its gross national product. Vaclav Smil of the University of Manitoba describes many of China's environmental challenges in The Bad Earth, a new book based on a study he conducted 2 years ago for the World Bank. Although Chinese newspapers and magazines distributed to foreigners paint a much rosier picture of the state of the environment, Smil's book, which stems mainly from articles published for the Chinese, and other, more recent Chinese articles confirm that the country's ecological problems are serious in both urban and rural areas. Almost all of China's major cities are heavily polluted because the nation is still largely dependent on coal as an energy source. Beijing is battling severe air pollution because of industrial contamination and dust from soil erosion from the surrounding countryside. Shanghai is contaminated by acid rain. Ninety percent of the country's urban sewage is not treated. Nor is much of the waste from industry before it is dumped into the waterways and used to irrigate crops. China has also stripped itself of forests which has led to soil erosion and flooding.

Smil, who is a professor in the department of geography and has written extensively on China's energy and environmental problems, said in an interview that China's environmental problems are 'no different than those of any other developing nations,' except that they are excerbated by the country's extremes in climate and its tremendous population. He contends that it is China's "staggering mistreatment of of the environment that may well be the most fundamental check on China's reach toward prosperity."

Smil believes that China's environmental problems are rooted in the country's drive to increase grain production and to industrialize. To boost grain production, for example, the government ordered vast tracts of forests and grasslands converted into cropland. But the efforts were largely unsuccessful and merely resulted in massive soil erosion. According to a 1983 issue of the Chinese Journal of Ecology, China annually loses 5 billion tons of soil through runoff.

Smil reports so much forest has been destroyed that China now only has about half the amount of forest as the United States, which is comparable in landmass. China's forests, he says, are rapidly receding-from the boreal stands of firs and pines in the northeast provinces to the mangroves of the southern island of Hainan. The Communist government has recognized the problem of deforestation since it took power in 1949 and has repeatedly initiated tree planting campaigns to replenish the timberlands. But Smil says that the survival rates have been "appallingly low, often much below 10 percent" because of careless planting, inadequate follow-up, and the wrong choice of tree species for a certain area. At the same time there is apparently a substantial amount of illegal lumbering.

Soil erosion has also been aggravated by the Chinese government's push to convert natural grasslands into crop-producing areas. In the northen areas of China, 170,000 square kilometers of former grassland has become desert because of failed attempts at reclamation and overgrazing. The efforts were largely unsuccessful because the grain crops were unsuited to the targeted areas.

With the goal to produce more grain and other food. China has also been using increased amounts of fertilizer and pesticides on its crops, which has generated more ecological problems. Because the chemicals have been improperly applied or overused, crops, soil, and water supplies have been contaminated, according to scientists in the Chinese journal Agricultural Environmental Protection. The article said that wheat and other grains tested from the Manchurian province Heilongjiang showed residual amounts of organic chlorides that were 20 times greater than the standards set by the United Nations. Vegetables grown near the provincial capital of Harbin contained 32 parts per million (ppm) of residual benzene hexachloride. The national standard is 0.2 ppm, the article said. Tissue samples from hogs, cattle, and sheep all had pesticide levels that exceeded national standards. The misuse of pesticides is already showing up in humans, the journal said.

While unwise agricultural policies have led to serious pollution, Li Ximing, the minister of Urban and Rural Construction and Environmental Protection, said recently that "environmental pollution in China is principally caused by industry." Much of the industrial pollution results from China's extremely inefficient use of coal, the country's principal source of energy. According to Smil, China is the least efficient nation for converting coal into commercial use. He says in 1979 China required 2.4 kilograms of coal equivalent for each dollar of gross national product. In contrast, the United States required nearly half the amount at 1.25 kilograms and Japan used even less at 0.6 kilogram

of coal equivalent. Examples of industrial pollution abound in Chinese publications. Some of China's largest chemical plants and oil refineries are located in the new industrial city of Lanzhou in northwest China. The companies "have contributed greatly to the country's prosperity," says the magazine China Reconstructs. But Lanzhou has paid a price for production. During the late 1970's, the air pollution was extraordinary. The Chinese government cracked down on the factories and the pollution was reduced, China Reconstructs says. But according to provincial newspaper Gansu Ribao, the residents still complain that the sky is "foggy in the morning and in the evening." Much of the pollution is apparently caused by sulfur dioxide that turns into acid rain.

Water quality in the cities has also become worse, according to an article in the Chinese publication Geographical Knowledge. In the Shanghai river delta, 95 percent of the industrial and domestic sewage is directly released into the waterway. In Nanjing, a plant producing aniline dumped 9,000 tons of sludge and 20,000 tons contaminated with the poisonous organic chemical into the water ways. Environmental Protection also reported that "there was a high frequency of illness among the workers at the plant." In 1978, pollution controls were installed and the situation greatly improved, the report said. Even so, the wastewater contaminated with aniline was only reduced by 60 percent.

To complicate pollution problems, the Chinese Government is now encouraging the use of urban sewage in agriculture because of water shortages in the countryside resulting from poor water management and droughts. One city's environmental protection office found trace amounts of cyanide and heavy metals in vegetable crops. The peasants complain that "sweet potatoes from these areas do not soften during cooking, rice..has an unusual taste, and eggplants and tomatoes irrigated with sewage...are likely to rot," according to a Hebei newspaper.

China has taken some positive steps, some that are symbolic and some that are more substantive, to curb pollution. Minister Li Ximing has given speeches acknowledging the country's environmental problems. He and others in China have stressed conservation as the best immediate solution to control pollution and prevent further ecological damage. He has also said that heavy industry should no longer be allowed to expand in major cities that are popular tourist spots, such as Beijing, Hangzhou, Suzhou, and Guilin, where "industry is already concentrated and environmental quality is poor." According to the government, heavy industry must now include pollution controls in future construction plans. In agriculture, the government has changed its policy so that regions may have more flexibility to choose which crops they may grow. The national campaign to plant more trees continues and the goal for 1985 is to ensure 65 percent survival of the seedlings.

Although the government seems to be saying all the right things in regard to environmental protection, substantial improvements are likely to be long in coming. "We are gradually paying more attention to the environment," says Peng Feifei, second secretary of the Chinese embassy in Washington. "Things are changing a lot." But according to Smil, the changes will have to be pursued much more aggressively if, in the long run, China wants to meet its economic goals.

(Science, 221, 4617 (September 23, 1983) pp1271-72)

INSA Golden Jubilee Symposia

1. Symposium on Physics and Chemistry of Surfaces at Indian National Science Academy, Bahadur Shah Zafar Marg, New Delhi from September 28-30, 1984.

   Topics for Discussion: Surface States, Adsorption, Chemisorption, Catalysis, Photoelectron Spectroscopy, and Surface Reconstruction.

   Contact Address: Professor S.K. Joshi, Department of Physics, University of Roorkee, Roorkee-247667.

2. International Symposium on Biological Monitoring of the State of the Environment (Bioindicators) at Indian National Science Academy, Bahadur Shah Zafar Marg, New Delhi, from October 11-13, 1984.

   Topics for discussion: Biomonitoring of air quality, Biomonitoring of drinking water quality, Biomonitoring of fresh water bodies, Biomonitoring of off shore & Marine Environment, Biomonitoring of heavy metals & soil environment and Future prospects of biomonitoring.

   Contact Address: Dr. T.N. Khoshoo, Chairman, International Symposium on Bioindicators, Indian National Science Academy, Bahadur Shah Zafar Marg, New Delhi-110002.

3. International Association of Seismology and Physics of the Earth'sInterior Regional Assembly at National Geophysical Research Institute, Hyderabad from 31st Oct. to 7th November, 1984.

   Topics for Symposia: Deep-seated Processes in Collision Zones; Seismicity & Seismotectonics of Asia -Nature of Seismic Sources, Induced Seismicity, Earthquake prediction, and Seismic evaluation; Terrestrial Heat Flow & Thermal Regimes; Lithospheric Structure beneath Asia; Physics of the Earth's Interior; Development of Geosciences in Developing Countries.

   Contact Address: Professor Vinod K. Gaur, Chairman, Executive Committee, IASPEI Regional Assembly, National Geophysical Research Institute, Hyderabad-500007.

4. Symposium on Tree Biology at Indian National Science Academy, New Delhi- from December 3-7, 1984.

Topics for discussion: Tree architecture & Wood biology, Physiology, Reproductive biology, Genetics and breeding, Pathology, Ecology, Utilization, Conservation.

Contact Address: Prof. H.Y. Mohan Ram, Convener, Symposium on Tree Biology, Department of Botany, University of Delhi.

5. International Symposium on Biomolecular Structure and Interactions at Indian Institute of Science, Bangalore, from December 17-22, 1984.

Topics for discussion: Theory of biopolymer conformations; studies on proteins, polypeptides, cyclic peptides and peptide antibiotics, polysaccharides, oligonucleotides and nucleic acids. Dynamics and folding of proteins; polymorphism and structural transitions of nucleic acids and oligonucleotides. Application of quantum chemistry to biomolecules. Structure and interactions of biomolecules using optical and spectroscopic techniques. X-ray crystallography and fibre diffraction studies of biological molecules. Synthesis and physicochemical studies of biologically active model peptides and oligonucleotides. Structural studies on glycoproteins, protein-nucleic acid complexes, viruses etc.; structure and organization of chromatin. Studies on membrane structure, trans-membrane channels and carriers, membrane transport and cell surface.

Contact Address: Prof. V. Sasisekharan, Convener, International Symposium on Biomolecular Structure and Interactions, Molecular Biophysics Unit, Indian Institute of Science, Bangalore-560012.

6. International Conference on Nuclear Physics, at Bhabha Atomic Research Centre, Bombay from Dec. 27-31, 1984.

Topics for discussion: Giant Resonances, High Angular Momentum States, Nuclear Fission and Nuclear Molecules, Pions, Isobars and Quarks in Nuclei, Nucleus - Nucleus Collision at High and Medium Energies.

Contact Address: Dr. B. Sinha, Secretary, International Conference on Nuclear Physics, Nuclear Physics Division, Bhabha Atomic Research Centre, Bombay-400085.